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State of Illinois
Department of Registration and Education
STATE GEOLOGICAL SURVEY DIVISION
John C. Frye, Chief

# GUIDE LEAFLET

## GEOLOGICAL SCIENCE FIELD TRIP

Sponsored by
ILLINOIS STATE GEOLOGICAL SURVEY, URBANA

# GALENA AREA

Jo Daviess County, Illinois and Lafayette County, Wisconsin

Galena 15-minute Quadrangle
Cuba City and New Diggings 7.5-minute Quadrangles

Leaders
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Urbana, Illinois
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GUIDE LEAFLET 1971 C

HOST: Galena High School

TO THE PARTICIPANTS:

The Geological Science Field Trip program is designed to acquaint Illinois residents with the landscape, the rock and mineral resources, and the geological processes that have led to their origin. With this program, we hope to stimulate a general interest in the geology of Illinois and a greater appreciation of the state's vast mineral resources and their importance to the over-all economy.

We encourage you to ask the tour leaders any questions that may occur to you during the trip. Discussion often clarifies points that otherwise would remain confused to many of the participants. We also invite your written comments upon the conduct of the trips so that we might improve them as much as possible.

Additional copies of this guide leaflet, as well as itineraries for field trips that have been held in the past, may be obtained free of charge by writing to the Illinois State Geological Survey. The itinerary maps for each field trip can be purchased for 10 cents each.

Several of the stops along this itinerary are located on private property whose owners have graciously given us permission to visit their lands. Please obey the instructions of your trip leaders and conduct yourselves in a manner that will show respect for the property owners' cooperation. Please do not litter, or climb on fences, and leave all gates as found, so that we may be welcome to return on future field trips. These simple rules of courtesy also apply to public property as well. For the convenience of those persons who may use this itinerary at some future time, the names and addresses of every private property owner are listed for the respective stops on a page at the back of this guide leaflet. Whenever possible, always attempt to obtain permission when visiting private property.

We hope that you enjoy today's field trip and will attend others in the future.

THE STAFF
EDUCATIONAL EXTENSION SECTION
ILLINOIS STATE GEOLOGICAL SURVEY

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GALENA GEOLOGICAL SCIENCE FIELD TRIP

## INTRODUCTION

The Galena area is situated close to the bluffs of the Mississippi River Valley in the southern part of the Wisconsin Driftless Section, a large area in extreme northwestern Illinois and southwestern Wisconsin that appears to have been bypassed by the Pleistocene glaciers during the last one million years (see attached map of the Physiographic Divisions of Illinois). The Driftless Area has some of the most rugged and scenic topography in Illinois. Only thin loess mantles the deeply dissected bedrock surface. To the south and east, the Driftless Area is bounded by the western edge of the Rock River Hill Country, a region that has a more subdued topography consisting of highly undulating, glaciated uplands. Streams of the field trip area flow south and southwest to the Mississippi River via a network of drainage lines that includes Sinsinawa River, Galena River, Smallpox Creek, and Apple River.

Geologically, the Galena area is situated north of the Illinois Basin at the southern margin of the Wisconsin Dome, a broad uplift centered in north-central Wisconsin (fig. 1). Bedrock consists of about 2,000 feet of lower Paleozoic limestone, dolomite, sandstone, and shale ranging in age from Croixan (late Cambrian) to Alexandrian (early Silurian) (fig. 2, in part). These marine sedimentary rocks were laid down layer by layer in the ancient seas that covered Illinois and the midcontinent region much of the time during the early part of the Paleozoic Era about 550 million to 400 million years ago. Only the upper 550 feet of these strata are exposed in the field trip area. These consist mainly of dolomite formations of Champlainian (middle Ordovician) and Alexandrian (early Silurian) ages. The Canadian (lower Ordovician) and Cambrian rocks are not exposed but are known from deep wells and from exposures farther north where they rise to the surface toward the Wisconsin Dome. The base of the Cambrian strata rests upon an ancient basement of Precambrian granitic rocks that are more than one billion years old. Younger Paleozoic sedimentary strata of Devonian, Mississippian, and Pennsylvanian ages occur farther to the south (see attached Geologic Map of Illinois). Rocks of these ages were also probably deposited in the Galena area, but they have been removed by erosion. Pennsylvanian rocks rest upon strata as old as Ordovician age in several localities in northern Illinois, indicating that considerable erosion occurred before the beginning of the Pennsylvanian Period.

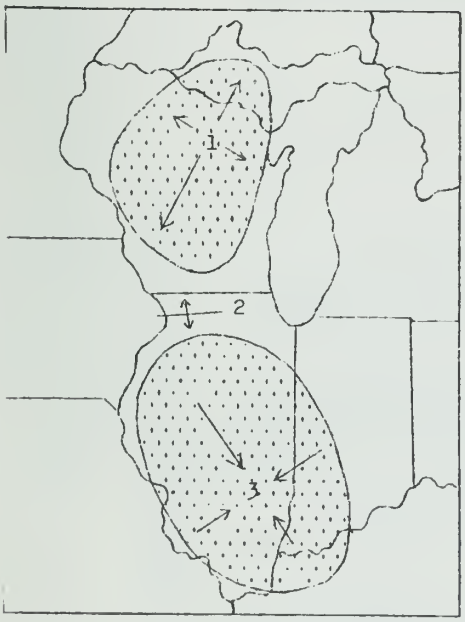


Fig. 1 - Index map showing locations of (1) the Wisconsin Dome, (2) the axis of the Savanna Anticline, and (3) the Illinois Basin.

Regionally, the Paleozoic strata are tilted gently southwestward, away from the Wisconsin Dome. This regional tilt is abruptly interrupted a few miles to the south by the Savanna Anticline, a narrow, elongated arch of the bedrock strata that trends east-west across Carroll County into eastern Iowa (fig. 1). South of the anticline, the Paleozoic strata are tilted gently downward into the Illinois Basin, a large spoon-shaped bedrock structure that occupies most of Illinois and adjacent parts of Indiana and Kentucky (figs. 1 and 3). In the deepest part of the basin, in southeastern Illinois, the Paleozoic strata thicken to more than 13,000 feet.

Jo Daviess County, where Galena is located, ranked first in lead and zinc production in Illinois during 1969. Crushed stone, common sand, and gravel,

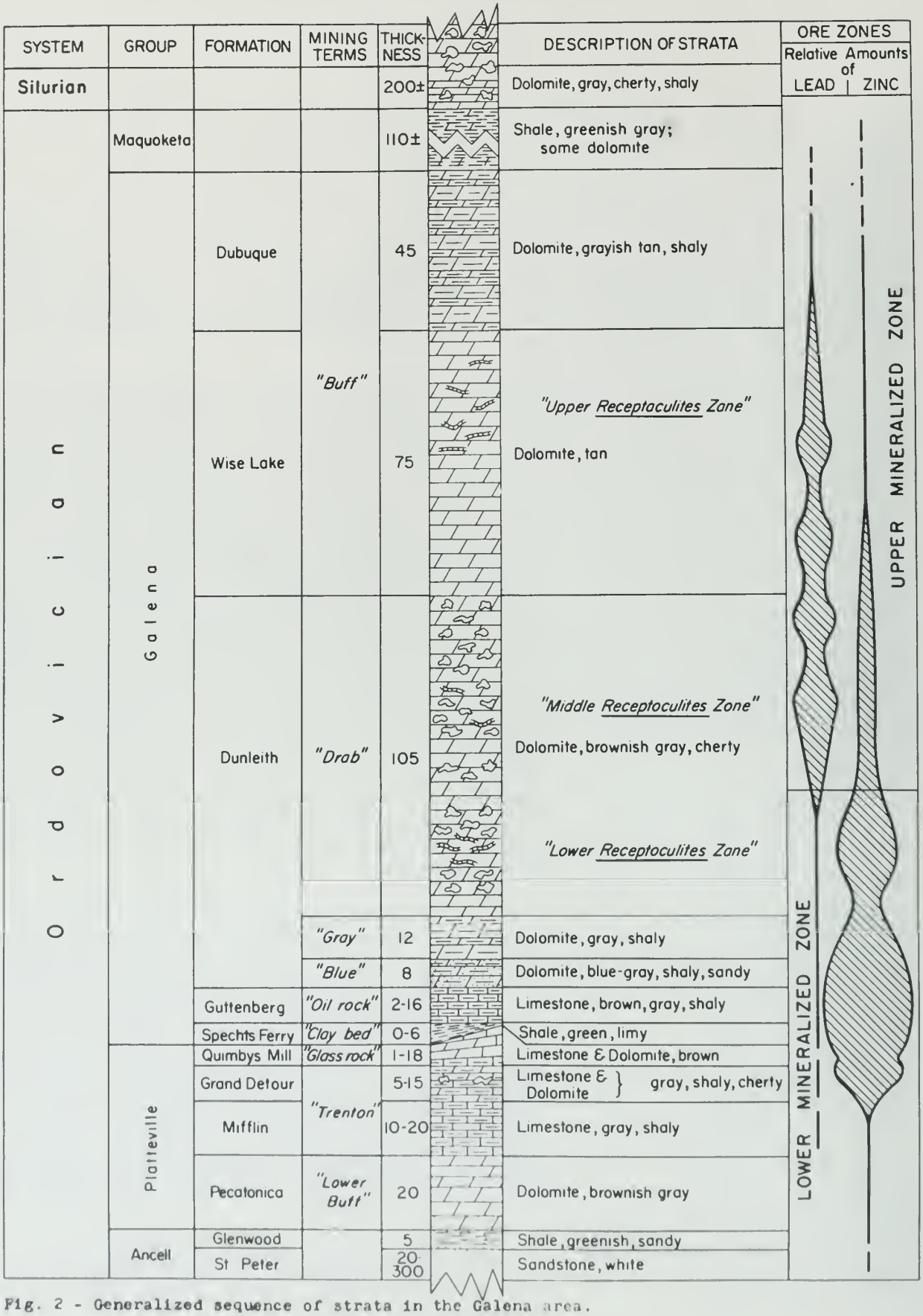



Fig. 2 - Generalized sequence of strata in the Galena area.

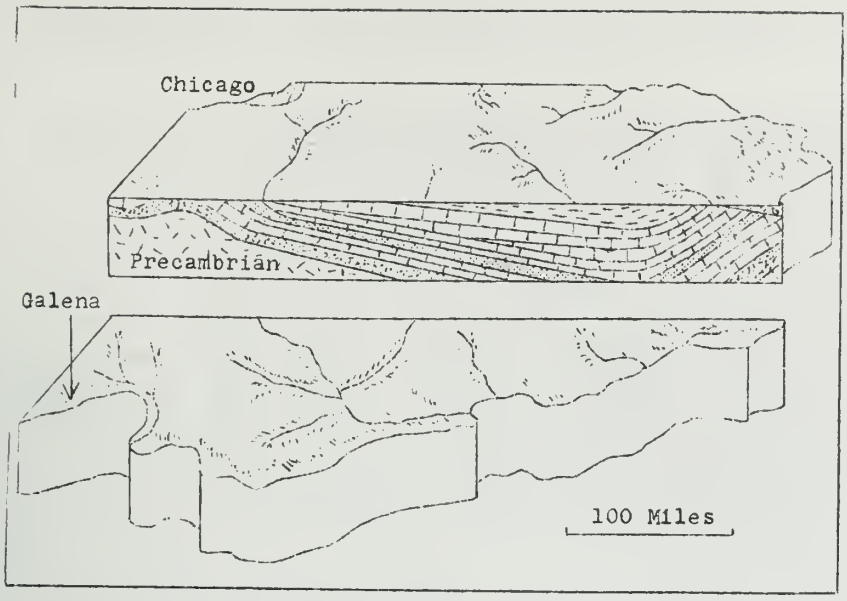



Fig. 3 - North-south cross section through Illinois showing the Paleozoic strata in the Illinois Basin.

which are used for various purposes in the building and construction industries, are also produced in the county. In 1969 Illinois produced almost 51.7 million tons of crushed stone valued at more than $78.4 million. The state also produced more than 17.5 million tons of common sand and more than 21.2 tons of gravel together worth more than $40.3 million. Zinc production totaled 13,765 tons, valued at over $4 million, and lead production totaled 791 tons, valued at $235,700. The total value of these particular mineral commodities for 1969 amounted to $123,013,155. Total value of all minerals produced in Illinois for the year amounted to $692.9 million. Minerals produced in Jo Daviess County during 1969 were valued at $3,038,685 ranking it 43rd out of 100 counties reporting mineral production for the year. In order of value, the minerals produced in the county are zinc, stone, lead, sand, and gravel.

## ITINERARY

| | | |
|---|---|---|
| 0.0 | 0.0 | Assemble on the northwest side of Galena High School. Enter highway and turn left (northwest). |
| 0.2 | 0.2 | STOP. Enter Highway 20. CAUTION. Continue straight ahead. |
| 0.5 | 0.7 | Toward the left notice the extremely even skyline across the river in Iowa. This may represent an old erosion surface, called the Dodgeville Peneplain. At Stop 4 this feature will be discussed in detail. |
| 1.3 | 2.0 | Junction of Routes 20 and 84. Continue ahead (north) on 84. |
| 0.9 | 2.9 | On the left in the distance is Sinsinawa Mound, an outlier of Silurian dolomite. This outlier and others like it will be discussed at Stops 4 and 6. |
| 0.4 | 3.3 | Ahead on the right is the chat pile (waste rock) of the Eagle-Picher Graham Mine. |
| 0.6 | 3.9 | Entrance on right to Graham Plant of Eagle-Picher Industries, Inc. |
| 1.3 | 5.2 | SLOW. Prepare to turn right. |
| 0.1 | 5.3 | Crossroads. Turn right (east) onto gravel road at sign that points to the Three Pines Campground and Lead Mine. |
| 0.3 | 5.6 | Notice the horizon ahead. See the front edge of the Silurian escarpment off to the right. Small patches of woods are developed on the Silurian, which caps the knobs in the distance. |

0.55 6.15 T-road from left. Turn left and head back toward Three Pines Vinegar Hill Lead Mine.

0.35 6.5 Stop 1. Three Pines Vinegar Hill Lead Mine (N½ SE¼ NE¼ and S½ NE¼ NE¼ Sec. 20, T. 29 N., R. 1 E.). NOTE: DO NOT take hammers into the mine and DO NOT pick at or molest the galena observed in crevices.

According to the owner, Mr. Earl Furlong, available information indicates that the Three Pines Vinegar Hill Lead Mine, or digging, was first operated between 1820 and 1830. The mine operated intermittently along an east-west crevice (see attachment, "The Zinc-Lead Deposits of Northwestern Illinois") and during the late 1870's yielded about 20 tons of lead ore (galena). The shaft was 47 feet deep, and ore was produced, apparently from the Wise Lake Formation (fig. 2). For many years the mine was inactive, but during the Depression (1937) the mine was re-opened by drifting (tunneling) back into the hillside from the east. About 1 ton of "cog mineral" (large crystals up to 1 foot across) was removed from the mine at that time.

Deeper mine shafts within a few hundred feet of this locality removed galena from the Wise Lake Formation and the upper part of the underlying Dunleith Formation. The Three Pines Vinegar Hill Lead Mine is situated north of Galena in what the early miners designated the "crevice area," developed generally southwestwardly for about 3 miles from the intersection of the Galena River and the state line. This region is honeycombed with old shaft mines and shallow diggings that were worked for lead ore during the 1800's. A few of the old shafts within a radius of 1 mile from this locality produced several hundred tons of galena in the early days of mining. By the close of the 1800's only small quantities of lead were being produced in the area, and most of this was recovered because it was associated with zinc ore (sphalerite).

About 0.6 mile southeast of this location is the site of Vinegar Hill Mining Company, which was one of the richer zinc producers in the area. Its shaft was about 200 feet deep, and the mine produced a total of 360,000 tons of ore, principally zinc, from 1908 through 1914 when it closed. The zinc ore occurs at greater depths than the lead ore. Zinc ore is most abundant in the lower Dunleith, the Guttenberg, Spechts Ferry, Quimbys Mill, and Grand Detour Formations, which are quite deep here.

## LEAD AND ZINC MINING IN THE UPPER MISSISSIPPI VALLEY REGION

### Historical Background

The Upper Mississippi Valley zinc-lead district, an area of zinc and lead mineralization in extreme northwestern Illinois, southwestern Wisconsin, and adjacent parts of Iowa, is one of the oldest continuously operating mining districts in the United States. It is not known exactly when the existence of lead ore in this region first became known. Jean Nicolet may have been the first white man to note its presence when he journeyed up the Mississippi River in 1634, but this is not confirmed by any record. There are reports that other French explorers had heard of Indian lead workings in the vicinity of Dubuque, Iowa, as early as 1658. However, Nicholas Perrot, a French commandant and Indian trader who is known to have viewed the Indian mines in 1682, is credited with the actual discovery of lead ore.

Lead mining has been carried on commercially to some extent in the region since at least 1690. It is known that the Indians sold lead to traders at Peoria in 1690, and in the same year Perrot established a small temporary trading post for

lead at East Dubuque. The Indians had undoubtedly been mining lead superficially for a hundred or more years prior to that time.

Commercial mining by the French and Indians continued on a small scale east of the Mississippi River for the next 100 years. In 1788 the Sac and Fox Indians gave Julien DuBuque permission to work mines on the west side of the river. DuBuque also opened a mine on the Illinois side near the site of Elizabeth. The lead mining industry continued to grow slowly until 1823, when rapid settlement of the area brought about a great expansion of the industry.

The principal lead ore mineral is galena, after which Galena, the county seat and largest city in Jo Daviess County, was named in 1827. Formerly La Point, Galena was the first city in this region to organize under a charter, and it grew rapidly as the mining industry expanded. Sphalerite, the ore of zinc, is also found with the galena, but until about 1850 galena was the only ore mineral recovered. Mines in the Galena vicinity were the first in the United States to produce large quantities of lead ore, and in 1845 a production of 27,000 tons was reported. This tonnage was 90 percent of all the lead produced in the United States, then the world's leading producer.

In the early days of mining the lead ore was found primarily in rich pockets or in open vertical fissures, both referred to as "crevices." These crevices occur at or near the ground surface in the dolomite bedrock which underlies the region. As the mining industry expanded, these rich, easily exploited crevice lodes became harder to find. The crevices were largely exhausted by 1870, and as a result lead production sharply declined. The search for lead ore was then extended deeper into the bedrock. Some additional galena was found, but the deep ores consisted primarily of the mineral sphalerite. These deeper ores occur in fractures in the dolomite as horizontal and inclined veins referred to as "flats" and "pitches," respectively. Sphalerite was first reported in 1839, but it was considered useless and was discarded by miners in search of lead ore. However, in 1852 a zinc ore reduction plant was opened near La Salle, and this mineral also became important to the economic development of the mining district. From 1852 to 1909 the total production of zinc ore was greater than that of lead ore in the same period. Although some lead ore is still being mined, zinc ore is the mainstay of the region's mining industry at the present time.

| | | |
|---|---|---|
| 0.0 | 6.5 | Leave Stop 1. Retrace route westward to Illinois Highway 84. |
| 0.35 | 6.85 | T-road intersection. Turn right (west) towards highway. |
| 0.85 | 7.7 | STOP. Intersection with Route 84. Turn right (north) on Route 84. |
| 0.8 | 8.5 | State line. Enter Wisconsin. |
| 0.05 | 8.55 | Wisconsin official marker (erected 1970) concerning land surveying on right. |

"THE POINT OF BEGINNING"

"Late in 1831, when Wisconsin was still in Michigan Territory, Lucius Lyon, U.S. Commissioner on the survey of the northern boundary of the State of Illinois, set a post and erected a mound of earth 6 feet square at the base and 6 feet high, at a point 1/2 mile east of here to mark the intersection of that boundary and the 4th Principal Meridian. The Wisconsin public land surveys were

begun here in 1832 and were completed 'up north' in 1867. Lyon surveyed 16 townships in S.W. Wisconsin in 1832-33, which opened this Territory for settlement. In 1833 Michigan Territory honored this veteran surveyor by electing him their Delegate to Congress. The post and mound he erected at this point were obliterated by fence and power line construction long ago, but the point is now preserved by a new concrete surveyor's monument. Every section corner monument in the state; the boundaries of each county, city, village, township, farm and lot; the position of roads, lakes and streams, all were surveyed and mapped from this Point of Beginning."

0.55 9.1 SLOW. Prepare to turn right.

0.3 9.4 Turn right.

0.9 10.3 Old abandoned galena mine on the right.

0.4 10.7 Stop 2. Exposure of Dunleith Formation in roadcut (NE¼ NW¼ SE¼ Sec. 31, T. 1 N., R. 1 E., Lafayette County, Wis.).

This road cut exposes about 25 feet of the Dunleith Formation, one of four formations into which strata of the Galena Group have been divided (fig. 2). As noted at Stop 1, the Galena Group contains the principal mineralized zones of the lead-zinc district. The Dunleith is about 125 feet thick in the Galena area. This exposure consists of thick, even beds of light brownish gray, finely crystalline, sucrosic (sugary) dolomite in the lower 20 feet; these thick beds are overlain by more thinly bedded strata. The dolomite is finely porous and vuggy with numerous fossil molds. Thin bands of irregular, light gray chert nodules occur along bedding planes. The abundant chert in the Dunleith is typical of the formation and distinguishes it from the overlying Wise Lake Formation, which otherwise is almost identical to it in color and physical properties.

The Dunleith is very fossiliferous, but the fossils are poorly preserved, consisting mainly of the internal casts of shells. Gastropods (snails) are the most abundant fossils, but pelecypods and brachiopods can be collected. The rock was probably deposited as limestone ($CaCO_3$) and at some later time altered to dolomite ($CaCO_3 \cdot MgCO_3$) by the addition of magnesium. This alteration or dolomitization of the rock was accompanied by recrystallization, which produced the sugary texture and destroyed the fossils.

The distinctive fossil, Receptaculites, is abundant in some beds. Because of its form, this most interesting fossil is commonly referred to as the "sunflower coral," although it is definitely not a coral nor even a sponge as once thought. At present it cannot be assigned to any known animal group.

0.0 10.7 Leave Stop 2. Continue ahead (east). Outcrops of Dunleith can be seen on both sides of the road.

0.6 11.3 Cross bridge. Continue ahead on blacktop.

0.3 11.6 SLOW. Prepare to stop.

0.2 11.8 Stop 3. Buncombe Section. Exposures of Dunleith, Guttenberg, and Spechts Ferry Formations (S½ NE¼ Sec. 32, T. 1 N., R. 1 E., Lafayette County, Wis.).

Downcutting of the river has exposed the lower part of the Dunleith Formation and the underlying Guttenberg and Spechts Ferry Formations of the Galena Group.

In the small draw on the left the exposed section includes the following units:

| | | |
|---|---|---|
| | "Drab" | Gray to brown mottled, vuggy dolomite, cherty in zones; 10'+ |
| Dunleith Formation | "Gray" | Gray to buff, slightly vuggy dolomite; thin green shale partings; 13' |
| | "Blue" | Blue-gray dolomite, sandy; thin green shale partings; 6' |
| Guttenberg Formation | "Oilrock" | Fine-grained, brown, thin- to medium-bedded dolomite and limestone, gray in lower part; wavy bedding planes; chalky on weathered surfaces; highly fossiliferous; thin red-brown shale layers; 13' |
| Spechts Ferry Fm. | "Clay-bed" | Clay, greenish, shaly; 1'+ |

The Champlainian (middle Ordovician) formations have persistent characteristic lithologies that are readily distinguished in outcrops and in the subsurface as mentioned earlier. Over the years of mining the lead and zinc deposits, the miners and drillers have given common names to these formations. The Guttenberg is called the "Oilrock" because some of the red-brown shales contain enough distillable oil to burn briefly when ignited by a match.

Some zones in the Guttenberg are extremely fossiliferous. The fossils are rather difficult to collect because of the dense character of the rock, but with patience one can collect excellent specimens of a large variety of fossils. These include trilobites, gastropods, pelecypods, cephalopods, crinoids, bryozoans, brachiopods, and corals. Especially abundant are the brachiopods Pionodema subaequata, Dinorthis pectinella, Rafinesquina trentonensis, Sowerbyella curdsvillensis, and Strophomena filitexta. For the most part, the original shell material of the fossils is no longer present. However, excellent molds and casts of fossils can be collected by breaking the rock.

The origin of chert, like the origin of dolomite, is not completely understood by geologists. The chert was apparently not deposited in its present form at the same time as the dolomite. Evidence for this is the fact that the chert is fossiliferous and also exhibits many of the sedimentary structures that are in the dolomite. Thus the chert appears to have replaced the dolomite. Colloidal and finely-divided silica were probably deposited as the siliceous hard parts of sponges and microscopic plants and animals. Later, after solidification of the dolomites (or the limestone which later changed to dolomite), this disseminated silica was dissolved, concentrated by solution, and redeposited as the irregular bands and nodules that are now present.

0.0 11.8 Leave Stop 3. Continue ahead (east).

0.2 12.0 T-road and bridge on right. Continue ahead and veer left.

0.3 12.3 Y-intersection. Veer right. Continue ahead.

0.35 12.65 Cross Galena River.

0.95 13.60 Turn left and enter Illinois.

0.25 13.85 T-road intersection. Turn right (south) and ascend hill.

1.4 15.25 T-road intersection. STOP. Turn left and then right.

0.65 15.9 Stop 4. Discussion of regional geomorphology (SE¼ SE¼ NE¼ Sec. 25, T. 29 N., R. 1 E.).

The topography of the field trip area has had a long history of development. Since the last Paleozoic sea withdrew at the end of the Pennsylvanian Period, about 270 million years ago, the Upper Mississippi Valley region has remained a land area. During this long erosion interval many hundreds of feet of Paleozoic strata have been stripped away. During the Pliocene Epoch, between 11 million and 1 million years ago, near the end of the Tertiary Period, the region was reduced to an erosional plain of very low relief known as the Dodgeville Peneplain.

A peneplain is a land surface that has been worn down by stream erosion and mass wasting to a low, nearly featureless plain that gradually slopes upward from the sea. Such an erosion surface would require a very long time to develop and would be characterized by sluggish streams flowing in broad valleys. Bedrock structures, such as anticlines, would have no influence on the topography but would be uniformly beveled.

Within the Galena Quadrangle the slope of the Dodgeville Peneplain and the dip of the Silurian dolomite are the same. The erosion surface corresponds to the dipslope. This fact is used by some geologists to argue that the upland surface is not a peneplain at all but a structurally controlled feature that formed when strata less resistant than the Silurian dolomite were stripped away. However, northward in Minnesota and Wisconsin the surface bevels Ordovician strata, which dip more steeply. Other arguments against the peneplain idea are the absence of a thick residual soil and the apparent control of present-day streams by bedrock joints, factors which should not exist if the region had been peneplained.

In the Driftless Area of Wisconsin, the Dodgeville surface is well preserved. In Jo Daviess County, Illinois, only remnants of the Dodgeville Peneplain are preserved as isolated, flat-topped ridges and knobs of Silurian dolomite (fig. 4). When the tops of these Silurian flats are joined by an imaginary plane, a surface representing the former peneplain is formed; it slopes gently southwestward from about 1,150 to 1,000 feet above sea level.

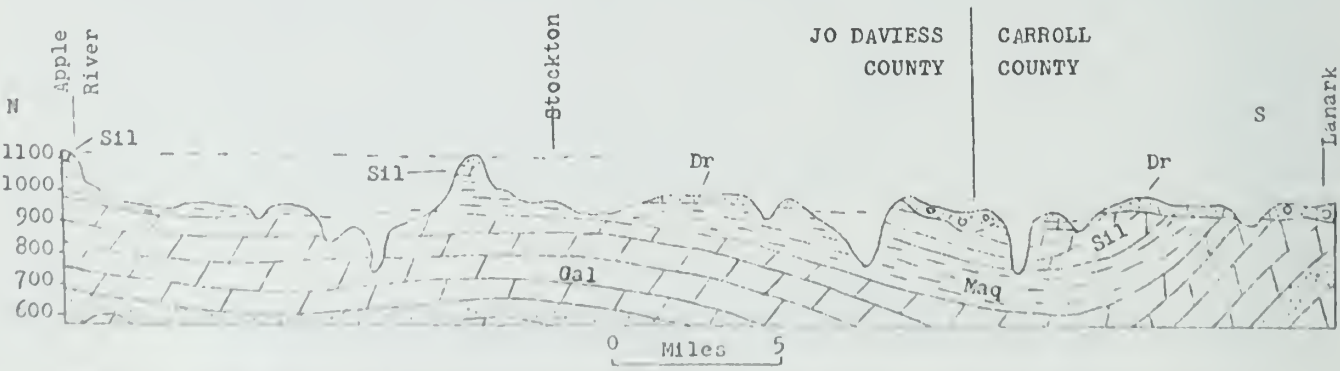



Fig. 4 - Cross-section showing Dodgeville (upper) and Lancaster (lower) erosion surfaces in northwestern Illinois and relationships to bedrock structure. Line of section is from Apple River to Stockton to Lanark. Dr, Glacial drift; Sil, Silurian dolomite; Maq, Maquoketa Shale; Gal, Galena Dolomite

After the Dodgeville Peneplain was formed, the region was uplifted and another, partial peneplain called the Lancaster Peneplain was eroded on the bedrock about 200 feet lower than the Dodgeville. The Lancaster Peneplain is extensively preserved on the bedrock surface of northern Illinois. It is well developed in the Driftless Area, and east of the Driftless Area it is a gently undulating surface covered by the glacial deposits. It closely coincides with the top of the Galena Dolomite and slopes southwestward from about 950 to 800 feet above sea level. The Galena area is near the southern edge of the Lancaster Peneplain. The Lancaster surface is evident by the evenness of the horizon toward the west, north, and east. This even appearance of the skyline is caused by the merging of near common summit levels when viewed from a distance.

The present topography of the Galena area is the result of stream dissection of the Lancaster Peneplain during the Pleistocene glaciations and modification of the dissected surface by glacial deposits. The Driftless Area is more rugged than adjacent areas because it was not glaciated. However, its mature topography is not a preglacial erosion surface as formerly believed. It was also eroded during the Pleistocene.

The relief of the bedrock surface is closely related to the establishment of the Mississippi Valley through the region during Nebraskan glaciation. Maximum relief was probably developed during the early part of the Kansan glaciation when the valley was eroded to its maximum depth by Kansan meltwater. After that, the valley was alternately aggraded by outwash and re-excavated during subsequent glacial and interglacial intervals. In the glaciated area to the east and south, till and outwash were deposited on the bedrock surface during the Illinoian glaciation. Loess was deposited on the uplands throughout the Upper Mississippi Valley region during the Wisconsinan glaciation. Deposition of a thick valley train in the Mississippi Valley during the late Wisconsinan Woodfordian and Valderan glaciations aggraded the valley to a level approximately 30 feet above its present floodplain. This aggradation also resulted in alluviation of the tributary valleys. Since the last glacier melted away, the Mississippi River and its tributaries have been deepening their valleys in the Wisconsinan alluvial deposits.

0.0 15.9 Leave Stop 4. Continue ahead (southeast).

0.7 16.6 T-road intersection. Turn left on Scales Mound road.

0.9 17.5 Stop 5. Abandoned quarry in Wise Lake Formation (Galena Group) (SE¼ SE¼ SE¼ Sec. 30, T. 29 N., R. 2 E.).

About 35 to 40 feet of the Ordovician Wise Lake Formation is exposed in this quarry. This formation is purer than the underlying Dunleith Formation and consists of thin- to medium-bedded, grayish brown, tan-mottled, non-cherty dolomite. In addition to vertical joints, there are in this quarry prominent fractures inclined about 65° to the horizontal which are probably related in origin to the time of mineralization of the region, although they themselves do not appear to be mineralized.

The Wise Lake is fossiliferous, but dolomitization of the strata, which were originally limestone, has largely destroyed the fossils. The presence of many molds of fossils gives the formation a finely porous aspect. For the most part, only poorly preserved specimens, mostly internal casts and molds of brachiopods and gastropods, can be collected, but with patience some good specimens can be found. Fairly good specimens of the fossil Receptaculites are abundant in the upper part

of the Wise Lake, here about 10 to 15 feet below the top of the quarry. This particular fossiliferous zone is the "Upper Receptaculites Zone" of the Galena Group.

A thin residual soil in Wisconsinan loess occurs above the Wise Lake in this quarry. The loess is thin, and the soil profile is partly developed into the weathered top portion of the dolomite.

## Origin of the Dolomites

Most geologists believe that dolomites were originally deposited as limestones by the chemical precipitation of calcium carbonate from sea water and by the accumulation of the calcareous remains of marine plants and animals. There is considerable evidence that the limestones were changed, or dolomitized, to dolomites at some time after their deposition.

During dolomitization, magnesium ions replace calcium ions in the atomic structure of the mineral calcite ($CaCO_3$). On the basis of the degree of dolomitization, a carbonate rock is classified as limestone (0-10% dolomite), dolomitic limestone (10-50% dolomite), calcitic dolomite (50-90% dolomite), or dolomite (90-100% dolomite). In pure dolomite, the calcium-magnesium ratio is about 1 to 1. Small amounts of ferrous iron usually replace some of the magnesium in dolomite, resulting in the characteristic light brown color of most weathered dolomite formations. Recrystallization also takes place during dolomitization, in many cases producing a sucrosic (sugary) texture that is also characteristic of many dolomites. Because of this recrystallization, primary sedimentary structures, such as current features and fossil remains, are destroyed or are poorly preserved.

Geologists do not agree on the origin of the dolomites. Some geologists believe that dolomitization takes place soon after deposition, when the unconsolidated limy sediments are still in contact with the sea water. Magnesium in the sea water is exchanged for calcium in the sediments by a reaction with the sea water that bathes the upper part of the sediments. Other geologists believe that after the limy sediments have been consolidated to limestone, dolomitization takes place by a reaction with magnesium-rich formation water (connate water) that was trapped in the limy sediments or in associated sandstones and shales during deposition. Still another theory holds that dolomitization is accomplished by ground water that becomes charged with magnesium from the zone of weathering at the earth's surface. The magnesium-rich ground water percolates through the pores and cracks (joints) in the limestones, altering them to dolomite. There is evidence that dolomite is precipitated directly from sea water under certain specialized environmental conditions and that many dolomites are primary in origin rather than secondary alteration products of limestone. However, the special conditions required for primary precipitation of dolomite generally are not found in most regions of present limestone deposition in the seas. Space does not permit an evaluation of all the various theories that have been proposed to explain dolomitization. Suffice it to say that the problem is a complex one.

0.0 17.5 Leave Stop 5. Continue ahead (south).

0.15 17.65 Railroad crossing. CAUTION.

1.3 18.95 On the right note the prominent ridge of Silurian dolomite.

1.3 20.25 T-road intersection from left. Continue straight ahead.

0.4 20.65 Stop 6. Scales Mound. Silurian Edgewood and Kankakee Formations (E½ NE¼ SW¼ and W½ NW¼ SE¼ Sec. 34, T. 29 N., R. 2 E.).

Scales Mound is capped by an outlier of the Silurian Kankakee Formation. The Kankakee Formation consists of cherty dolomite, which is quite resistant to erosion. The lower slopes of the mound are formed by the softer, argillaceous (clayey) Silurian Edgewood Formation. At the base of the mound, along the roadcut, the soft Ordovician Maquoketa Shale is exposed. The gentle slopes in the foreground are also developed on Maquoketa Shale, and beyond toward the north and west is the dissected Lancaster erosion surface on Galena Dolomite.

About 20 miles to the north two other Silurian outliers, the Platte Mounds, are visible. Toward the west Sinsinawa Mound stands prominently above the Lancaster Peneplain. Toward the southwest are remnants of the Silurian escarpment over which the itinerary will pass later.

The Kankakee Formation exposed here consists of light tan, cherty, thin-bedded dolomite. Bedding planes are undulating. Outcrop surfaces are coated with brilliant orange algae. In places along the exposure the bedding planes die out laterally into massive dolomite, which may represent small reefs. These contain fragments of stromatoporids, colonial, reef-building animals, now extinct, that may be related to the corals. Other fossils are scarce, but in a few beds there are scattered fragments of silicified colonial corals, brachiopods, and crinoid columnals.

Note the large slump blocks which have slid down on the underlying shale.

0.0 20.65 Leave Stop 6. Continue ahead (south).

0.15 20.8 Turn left (east).

0.05 20.85 STOP. Y-intersection. CAUTION. Dangerous intersection. Continue ahead (east) on blacktop road.

1.0 21.85 SLOW. Prepare to turn left.

0.1 21.95 Crossroads. Turn left (north) toward Scales Mound.

0.45 22.4 CAUTION. Enter village of Scales Mound.

0.15 22.55 T-road intersection. Turn left and STOP.

Stop 7. Exposure of Cincinnatian (upper Ordovician) Maquoketa Shale in railroad cut (SW¼ NE¼ SW¼ Sec. 26, T. 29 N., R. 2 E.). Walk westward ¼ mile along railroad to exposure. Fossil collecting stop.

This railroad cut exposes a thick section of gray shale and phosphatic sediments in the lower part of the Maquoketa Group. The base of the shale overlies buff-colored dolomite of the middle Ordovician Dubuque Formation, the uppermost formation of the Galena Group. The shale exposed here belongs to the Scales Formation, one of several formations into which the Maquoketa Group has been divided. This exposure is the type section by which the Scales Formation has been formally defined. Its name is taken from the village of Scales Mound. Of particular interest here are the phosphatic sediments, which represent unusual conditions of deposition which occurred only during Maquoketa time in Illinois, and the contact between the Scales and Dubuque Formations, an ancient surface of erosion which represents a major withdrawal of the sea from this region during Ordovician time.

This railroad cut is one of the best exposures of the lower part of the Maquoketa Group in Illinois. As shale soon breaks down by weathering, most natural exposures are poor and grassed over. The Maquoketa consists mostly of light gray and greenish gray shale with thin even beds of light brownish gray siltstone. The lower 4 feet of the shale is dark brownish gray or dark gray (almost black), phosphatic, and carbonaceous shale. This dark colored shale is very hard and slaty. At the bottom of the shale is a thin 2- to 6-inch layer of shaly, bluish gray phosphate rock composed of numerous small, pyritic, and phosphatic fossils, consisting mostly of pelecypods, gastropods, and other mollusks, mixed with phosphatic clay and shiny black grains, pellets, and nodules of phosphorite. The phosphate rock is also partially cemented by pyrite. Phosphorite is calcium-fluoro-phosphate, a variety of the mineral apatite that is commonly found in small quantities in marine sedimentary rocks. The fossils originally consisted of calcium carbonate, which was replaced by the pyrite and phosphorite. The phosphatic fossils are black, gray, and brownish gray. The pyrite weathers easily, with the result that the phosphate rock soon becomes rusty and loosely granular, making the phosphatic fossils easy to collect. A second bed of phosphate rock, about 8 inches thick, exactly like the lower one and containing the same fauna, occurs about 3½ feet higher.

The lower bed of phosphate rock forms a crust-like layer on the top of the Dubuque Formation. This layer of phosphate rock is the famous "depauperate zone" that occurs widely at the base of the Maquoketa Shale throughout the Midwest. Most of the fossils of the depauperate fauna are very small, usually ¼ inch or less in diameter. Because of the abundance of pyrite and carbonaceous material in the phosphatic sediments, many geologists formerly believed that the fossils had been dwarfed in a restricted marine environment of poorly circulating, oxygen-deficient waters. However, study has shown that the depauperate fauna consists mostly of normal size individuals of species that never grew any larger. What is unusual is that so many species of small animals were living together in the same environment. Forty-four species have been identified in the depauperate fauna, although not all are in any one place. Among these are species of Ctenodonta, Vanuxemia (pelecypods), Trochonema, Cyclonema, and Hormotoma (gastropods), which are illustrated on the fossil plate.

The top of the Dubuque Formation is an erosion surface known as a disconformity. Prior to deposition of the Maquoketa Shale, the middle Ordovician sea had withdrawn and this region was a land area exposed to erosion. The phosphatic sediments were deposited on this erosion surface during the early part of the late Ordovician re-invasion by the sea. The type of environment in which the Maquoketa phosphates were deposited is not exactly known, but probably it was not a restricted environment. In modern seas, phosphatic sediments are forming in unrestricted, open ocean environments at intermediate depths (200 to 1,000 feet) where bottom waters are freely circulating and well oxygenated. These areas are usually platforms bordering deep basins from which cold, phosphate-rich waters upwell toward the surface. Over these relatively shallow platforms, the upwelling basin waters are warmed, resulting in supersaturation of the sea water with dissolved phosphate. This supersaturation causes chemical precipitation of phosphorite, in the form of crusts or nodules, on the sea floor. The upwelling waters are also rich in other dissolved nutrients, and these support the growth of large populations of microscopic planktonic plants and animals in the surface waters. The plankton extract phosphate from the sea water during their life processes. When they die, their remains settle to the bottom, adding additional phosphate and organic carbon to the bottom sediments. Phosphate from the water also replaces calcium carbonate in the shells of benthonic (bottom dwelling) and planktonic animals that accumulate with the phosphatic sediments.

Almost no land-derived sediments (sand, silt, or clay) and no limestone are being deposited in present-day areas of phosphorite deposition. This nondeposition of other sediment types is a very important factor in the formation of concentrations of phosphorite. Phosphorite accumulates so slowly that the deposition of large quantities of other sediments would dilute the phosphorite and prevent its concentration. Phosphorite nodules would not form if they did not remain in contact with the sea water for a very long time. (On parts of the sea floor off the coast of southern California, phosphorite nodules similar to those at the base of the Maquoketa Shale are growing at the rate of only a few millimeters per thousand years.)

Perhaps an environment similar to the modern phosphate environments existed during late Ordovician time when the phosphatic nodules and shales of the Maquoketa were deposited. At the beginning of the late Ordovician submergence, very little mud was carried into the sea from the land while the dark phosphatic shale was being deposited. Sedimentation was especially slow during the growth of the phosphorite nodules and deposition of the phosphate rock. The concentration of phosphate ended when large amounts of mud and silt were washed into the sea from the land and the overlying non-phosphatic light gray shales and siltstones were deposited. These sediments are almost barren of fossils because most bottom-dwelling animals could not tolerate the muddy conditions.

| | | |
|---|---|---|
| 0.0 | 22.55 | Leave Stop 7. Retrace route to south. |
| 0.15 | 22.7 | Leave village of Scales Mound. |
| 0.45 | 23.15 | STOP. Crossroads. Turn right (west) on blacktop. |
| 1.1 | 24.25 | Y-intersection. Veer left on blacktop. The itinerary gradually ascends the Silurian ridge seen from Stop 6. For about 2 miles the road runs along the ridge on the level of the Dodgeville Peneplain. |
| 3.45 | 27.7 | Abandoned quarry in Silurian dolomite on the right. The road is crossing Maquoketa Shale. Note the gentle slopes. |
| 1.3 | 29.0 | T-road intersection from the right. Continue straight ahead. The slopes here are underlain by Galena Dolomite. |
| | | T-road from left. Continue straight ahead on blacktop. |
| 2.8 | 31.8 | Abandoned quarry in Galena Dolomite on the right. |
| 0.8 | 32.6 | Bridge over railroad. |
| 0.5 | 33.1 | Entering Galena. SLOW. |
| 0.3 | 33.4 | Turn left on west side of steel city maintenance building for entrance to park and picnic area. |
| | | <u>Stop 8</u>. Lunch (W½ SE¼ SW¼ Sec. 16, T. 28 N., R. 1 E.). |
| 0.0 | 33.4 | Leave Stop 8. Turn left and continue ahead (west). |
| 0.5 | 33.9 | T-intersection. Turn right on Meeker Street. CAUTION. Cross bridge over Hughlett Branch. |

| | | |
|---|---|---|
| 0.1 | 34.0 | Turn left on Bench Street. CAUTION. |
| 0.1 | 34.1 | STOP. Intersection with Franklin Street. Continue straight ahead and veer slightly to right. |
| 0.15 | 34.25 | STOP. Continue straight ahead. |
| 0.45 | 34.7 | STOP. Intersection with Routes 20 and 84. Turn left onto highway and cross bridge. CAUTION. |
| 0.05 | 34.75 | Cross bridge over Galena River and railroad. |
| 0.25 | 35.0 | Turn right (south) onto 4th Street at sign pointing toward ski lodge. |
| 0.1 | 35.1 | Veer left on blacktop. Continue straight ahead on Blackjack Road. |
| 1.6 | 36.7 | Y-intersection. Turn left. |
| 0.55 | 37.25 | Y-intersection. Keep right. |
| 1.2 | 38.45 | CAUTION. Descend steep grade. Note the loess exposure in the roadcut on the left. |
| 0.3 | 38.75 | Cross Smallpox Creek. |
| 1.25 | 40.0 | Stop 9. Sunset Point (SW¼ SW¼ SE¼ Sec. 3, T. 27 N., R. 1 E.). |

From this vantage point there is an excellent view of the Dodgeville and Lancaster Peneplains. The conspicuous mound toward the northwest is Pilot Knob.

During the Pleistocene Epoch, commonly referred to as "The Great Ice Age," an extensive continental ice cap covered the northern hemisphere. The portion of the ice cap that covered northern North America has been named the Laurentide Ice Sheet. Beginning about 1 million years ago and ending only 5,000 years ago, southward expansions of the ice sheet caused four major glacial invasions of Illinois and the Midwest. The ice that entered Illinois came from two centers, one each in central and eastern Canada, called the Keewatin and Labradorean, respectively (fig. 5). Each of the four major glacial advances were followed by long, warm interglacial intervals during which the glaciers melted completely away (see attached Pleistocene Time Table). The last glacier, the Wisconsinan, melted from northeastern Illinois only about 10,000 years ago.

Fig. 5 - Maximum extent of the Laurentide Ice Sheet. The Keewatin (K) and the Labradorean (L) centers are shown.

In order of occurrence, the glaciations of the Midwest have been named the Nebraskan (fig. 6), the Kansan (fig. 7), the Illinoian (fig. 8), and the Wisconsinan (fig. 9). The names are derived from the states where glacial deposits of these ages are best developed or were first described. Although the field trip area apparently was not glaciated, Pleistocene glaciers passed nearby, and their influence is evident in the topography and loess deposits of the area.

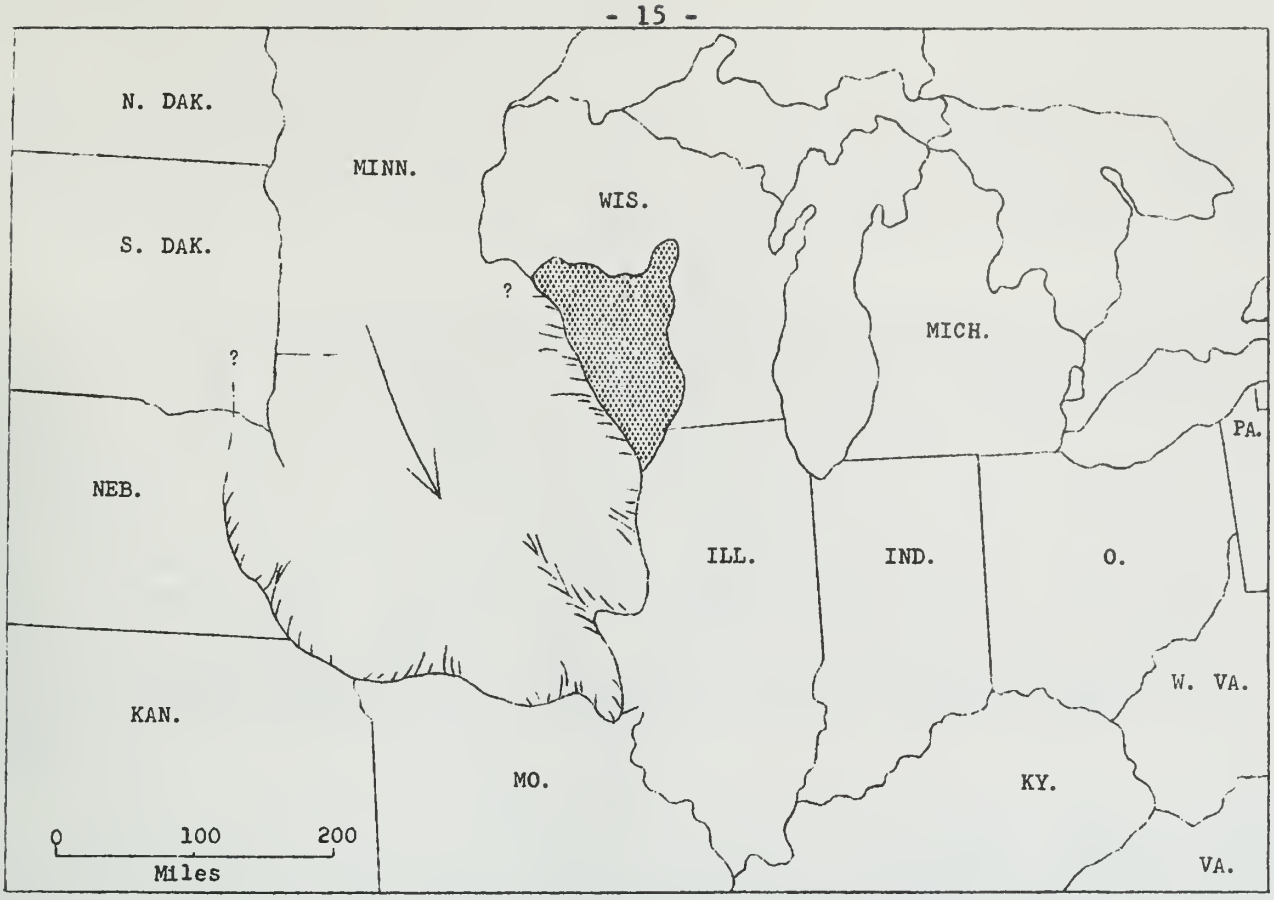



Fig. 6 - Maximum extent of Nebraskan glaciation (1,000,000 years ago). Driftless Area shown by stippled pattern. Arrow indicates direction of ice movement.

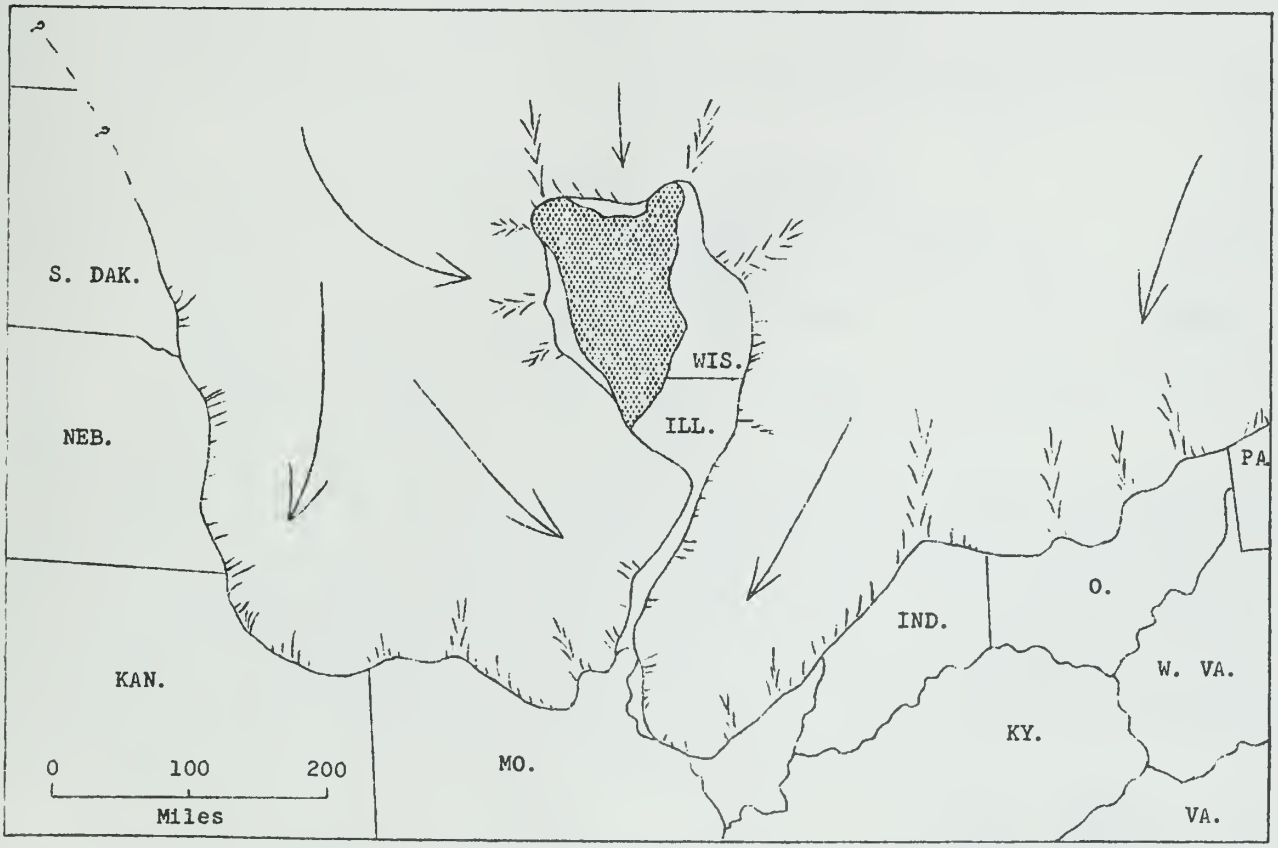



Fig. 7 - Maximum extent of Kansan glaciation (700,000 years ago).

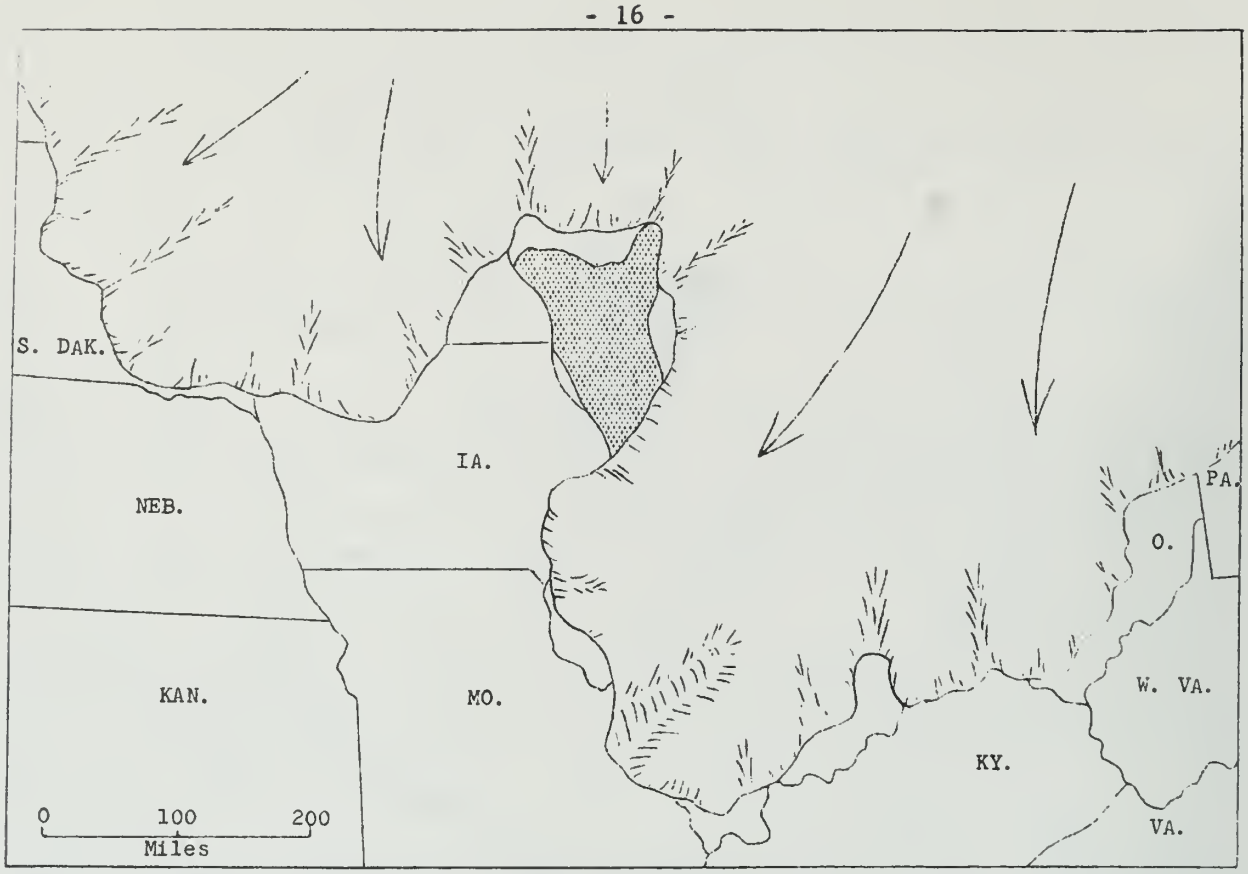



Fig. 8 - Maximum extent of Illinoian glaciation (250,000 years ago). Driftless Area shown by stippled pattern. Arrows indicate direction of ice movement.

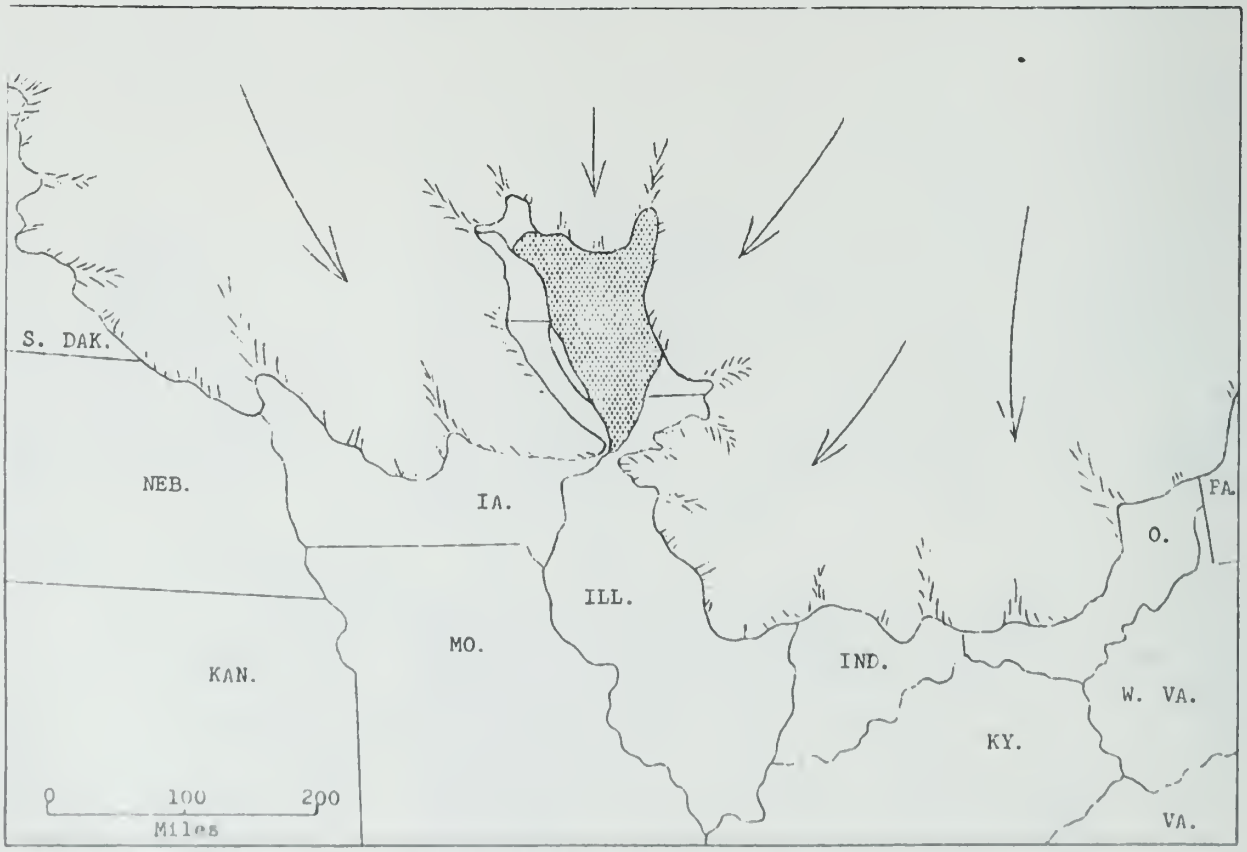



Fig. 9 - Maximum extent of late Wisconsinan glaciation (22,000 years ago).

The glaciers transported vast amounts of rock and soil debris that was eroded from the land areas over which they moved. As the glaciers melted, these materials, known as drift, were deposited. Within the areas that were covered by the ice there are extensive surficial deposits of ice-laid material, called till. Areas that were covered by ice several times sometimes have more than one layer of till.

Water-laid materials, known as outwash and consisting of clay, silt, sand, and gravel, were deposited by sediment-laden meltwaters flowing away from the ice fronts during both the advances and retreats of the glaciers. Near the glacial margins, in places where meltwater was not confined to definite channels, the outwash was often deposited as thin blanket-like deposits called outwash plains. Where the meltwaters were confined to valleys, narrow channel deposits, known as valley trains, were deposited. River valleys, such as the Mississippi, Illinois, and Ohio Valleys, provided major channelways for the escaping meltwaters. These valleys were greatly widened and deepened in the bedrock during times of greatest flood. During times when the meltwater floods were waning, these valleys were partially filled with outwash far beyond the ice margins. In the Mississippi Valley near Savanna, the valley train is more than 300 feet thick. Many river valleys in areas covered by the ice were completely buried by glacial deposits. The meltwaters also cut new valleys and caused numerous changes in the drainage system, some permanent and some temporary.

Deposits of wind-blown silt, called loess, which form the surface materials over extensive areas of Illinois, are also the result of glaciation. The silt was blown from floodplains of the valley trains. Most loess deposition occurred in the fall and winter seasons, when colder conditions caused meltwater floods to recede, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, the winds prevailed westerly, and as a result, the loess deposits are thickest on the east side of the source valleys. The loess thins rapidly away from the valleys. The valley train of the Mississippi Valley was the source of loess in the Galena area, and along the bluffs the loess is as much as 35 feet thick.

0.0 40.0 Leave Stop 9. Continue ahead (south and east).

0.65 40.65 T-road intersection from left. Continue straight ahead.

0.25 40.9 Stop 10. View to right (west) of Mississippi Valley (SW¼ SW¼ NW¼ Sec. 11, T. 27 N., R. 1 E.).

Toward the west is an excellent view of the Mississippi Valley and the Dodgeville Peneplain in Iowa.

The discovery by Survey geologists of Nebraskan outwash high on the bluffs east of the Mississippi Valley near East Dubuque is evidence that the ancestral Mississippi River was probably not entrenched in its present valley in the Galena area until after the Nebraskan glaciation. These outwash deposits consist of coarse gravel overlying lake sediments in small, shallow channels on the dolomite bedrock, 200 feet above the floodplain. The position of the valley from the vicinity of St. Paul, Minnesota, southward along the west side of the Driftless Area closely follows the margin of the Nebraskan glacial deposits. Thus, it appears that the position of the valley is the result of the Nebraskan glaciation and the stream was established marginal to the ice during the maximum advance of the glacier.

Just south of Galena the Mississippi Valley cuts through a prominent north-facing escarpment (bluff) of Silurian dolomite (fig. 10). The front of the escarpment

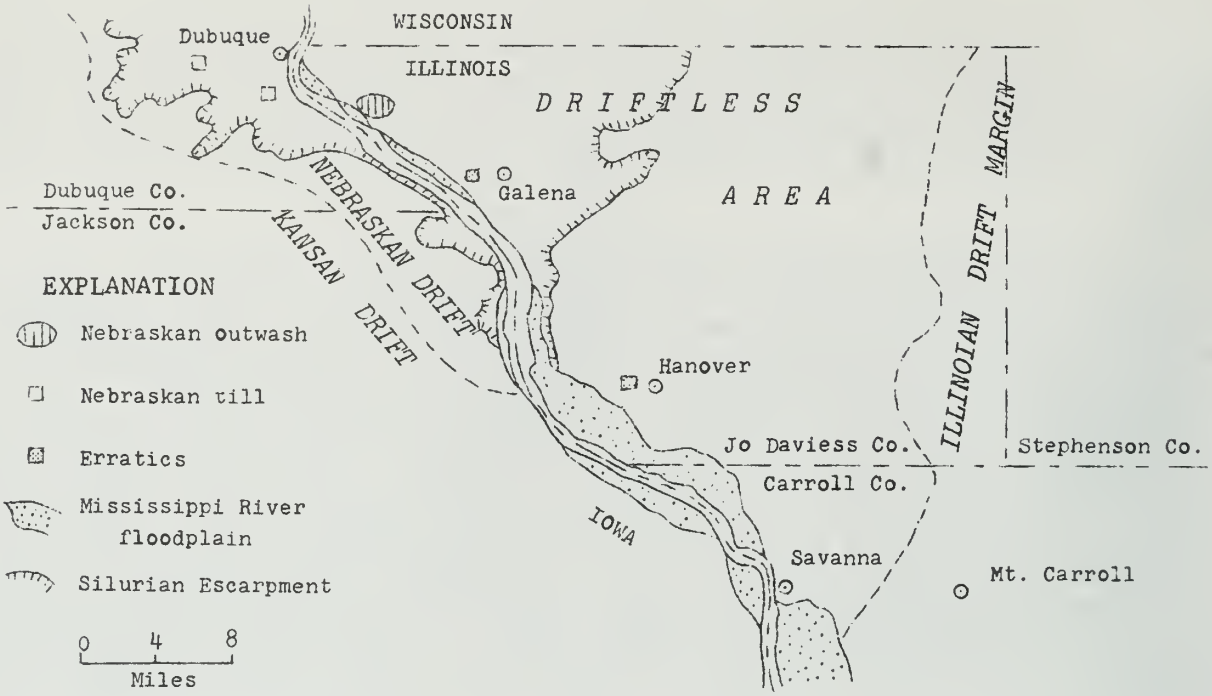



Fig. 10 - Occurrences of Nebraskan drift and erratics in the Driftless Area in Illinois.

stands about 200 feet above the level of the Lancaster Peneplain. This escarpment, or cuesta, is the erosional edge of the Silurian dolomite formations that dip gently southwestward off the Wisconsin Dome.

At the beginning of the Ice Age, the Upper Mississippi Valley region of northwestern Illinois, northeastern Iowa, and southwestern Wisconsin was a plain of low relief at the level of the present uplands (Lancaster Peneplain). The Silurian escarpment was a continuous divide extending across northwestern Jo Daviess County and into Iowa. Streams flowed northward and southward from the divide in broad, shallow valleys, high above the present drainage. There is no evidence that a major south-flowing stream existed in the Galena area, but several of the major tributaries to the Mississippi may follow courses that were established at that time. Farther south, an ancestral river, called the Ancient Iowa River, had its headwaters in east-central Iowa. This ancient valley, below Muscatine, is occupied by the present-day Mississippi River.

Fig. 11 - Major drainage in Illinois after the Nebraskan glaciation.

With the advance of the Nebraskan glacier, the first of the Pleistocene glaciers to invade the Upper Mississippi Valley region, northward drainage was blocked and a meltwater lake formed at the base of the Silurian escarpment, north of Galena. The meltwater eventually spilled over the divide at Galena and eroded a channel through the escarpment. The water then flowed southward and eroded a valley along the margin of the Nebraskan glacier. By the end of the Nebraskan glaciation, the Mississippi River had established its valley along the west side of the Driftless Area southward as far as Fulton in Whiteside County (fig. 11). From there, it followed a course southeastward to the present big bend of the Illinois Valley in Bureau County. The river then followed the present course of the Illinois Valley to its junction with the Ancient Iowa River at Grafton in Calhoun County. Except for a temporary westward diversion by the

Illinoian glacier, the Ancient Mississippi followed its course from Fulton to the big bend and southward along Illinois Valley until the Wisconsinan glaciation. During the Woodfordian advance, the river was permanently diverted westward, where it assumed the valley of the Ancient Iowa River along the west side of Illinois, a course it still follows. Its former valley from Fulton to the big bend, known as Princeton Valley, was buried by Wisconsinan drift.

0.0 40.9 Leave Stop 10. Continue ahead (south).

1.35 42.25 Approximate position of ½-mile long east-west Chicago and Northwestern Railroad tunnel, nearly 200 feet below the road.

1.0 43.25 STOP. Crossroads. Continue straight ahead.

0.15 43.4 T-road intersection from right. Continue straight ahead. In cuts along this road note the exposures of loess. The loess consists of silt which was blown from the floodplain of the Mississippi River during Pleistocene time.

1.35 44.75 T-road intersection from right. Continue ahead and veer left.

0.6 45.35 Descend steep hill. CAUTION.

0.3 45.65 T-road intersection from left. Continue ahead.

1.2 46.85 Note the terraces on both sides of Beaty Hollow. Similar terraces occur along Galena River, Sinsinawa River, and Smallpox Creek.

The deposition of outwash in the Mississippi Valley during Wisconsinan time raised the valley floor and blocked the river's tributaries. This blockage caused alluviation of the tributary valleys upstream from their mouths. Resumption of downcutting later formed the terraces.

0.5 47.35 Crossroads at Blanding. Turn right.

0.25 47.6 Note the sand dunes on the right.

1.0 48.6 Railroad crossing. CAUTION. TWO TRACKS. Veer right and continue ahead.

0.5 49.1 Railroad underpass.

0.15 49.25 Y-intersection. Veer left.

0.25 49.5 CAUTION. For the next few miles the road is very rough and narrow.

0.45 49.95 <u>Stop 11</u>. Abandoned crevice mine in Galena Dolomite (NW¼ NE¼ SE¼ Sec. 28, T. 27 N., R. 1 E.).

For the next mile or so the river bluff is honeycombed with abandoned lead mines, which may date from pre-Civil War days. These deposits were very rich but small. The lead ore occurred in fissures along joints in the dolomite. A more detailed discussion of the crevice deposits is given in the attachments at the back of the guide leaflet.

Some of the mine shafts are still open and large enough to enter. However, the mines were dangerous when they were being worked and are even more dangerous now. DO NOT ENTER ANY OF THE MINES!

1.3 51.25 Ski chair lift.

1.2 52.45 T-road intersection from right. Turn right.

0.65 53.1 STOP. Intersection with road from right. Continue ahead and veer left.

0.2 53.3 Railroad crossing in Rice. CAUTION.

1.4 54.7 Turn sharply right. Do not go through the gate, but drive to the right around the edge of the mine area.

0.3 55.0 Stop 12. Mineral collecting in waste piles of Gray Mine (NW¼ NW¼ NW¼ Sec. 10, T. 27 N., R. 1 E.).

Calcite, pyrite, galena, and sphalerite can be collected here. The waste piles are rather old and weathered, but with patience one can collect some fairly good specimens. Note the blocks of Galena dolomite containing *Receptaculites oweni*.

In addition to the minerals noted above, the following minerals have been reported from the Zinc-Lead District: anglesite (lead sulfate), barite (barium sulfate), calamine (zinc silicate), cerussite (lead carbonate), chalcopyrite (copper and iron sulfide), hydrozincite (zinc carbonate), limonite (hydrous ferric oxide), marcasite (iron sulfide), melanterite (hydrous ferrous sulfate), psilomelane (hydrous manganese oxide), selenite or gypsum (hydrous calcium sulfate), smithsonite (zinc carbonate), quartz, and native sulfur.

END OF TRIP. DRIVE CAREFULLY ON YOUR WAY HOME.

NOTE: To return to Galena, turn right at mine entrance and follow dotted itinerary portion on itinerary map. Galena and U.S. Route 20 about 5 miles away. Hanover and Illinois Route 84 about 13 miles to southeast. Turn left at mine entrance.

Additional reading reference:

The Geology of the Upper Mississippi Valley Zinc-Lead District: U.S. Geol. Surv., Prof. Paper 306, 1959. 310 p.

## Property Owners

Stop 1. Mr. Earl Furlong, Galena, Illinois 61036.

Stop 5. Mr. John W. Stienstra, Rural Route 1, Scales Mound, Illinois 61075.

Stop 6. Mr. Alois J. Bilgri, Rural Route 1, Scales Mound, Illinois 61075.

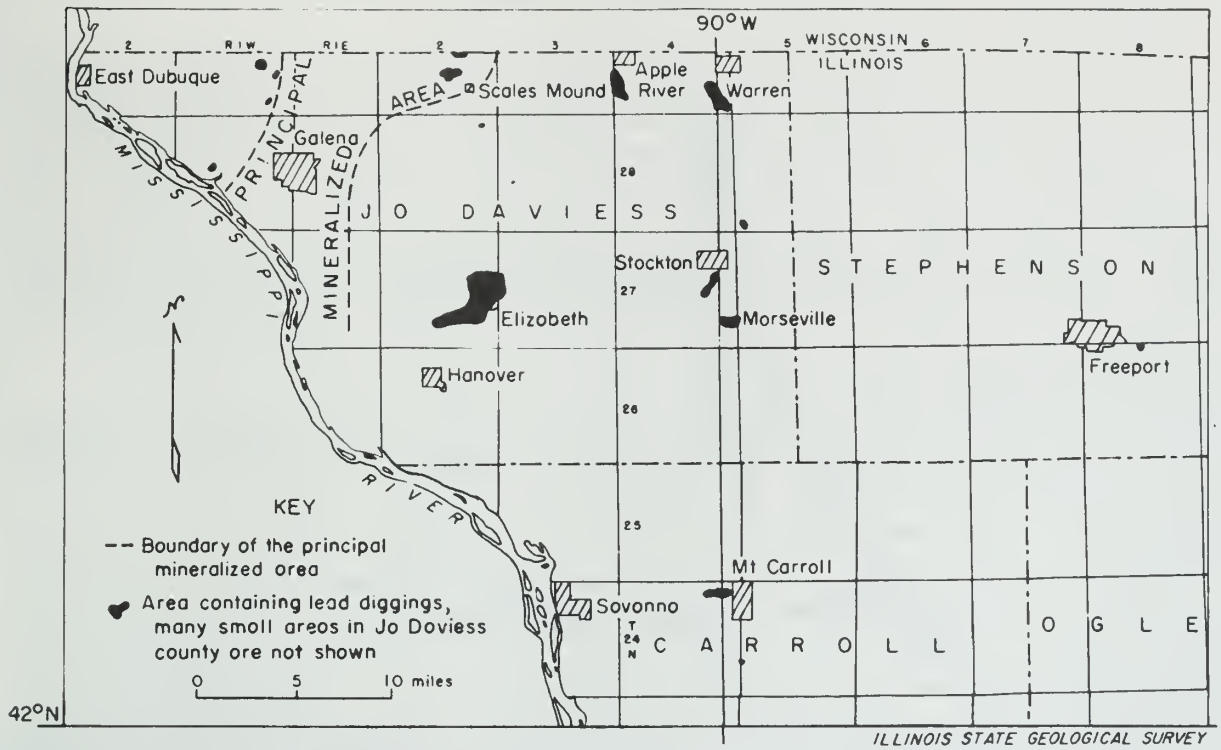
Stop 7. Illinois Central Railroad, 135 East 11th Place, Chicago, Illinois 60605.

Stop 12. Eagle-Picher Industries, Inc., P.O. Box 1040, Galena, Illinois 61036, and Mr. Ed Miles, Galena, Illinois 61036.

# THE ZINC-LEAD DEPOSITS OF NORTHWESTERN ILLINOIS

## Location

The principal mineralized area in which the zinc-lead deposits in northwestern Illinois have been found occurs in Jo Daviess County in a belt from 5 to 10 miles wide and 15 miles long, extending approximately northeast through Galena from the Mississippi River to the Wisconsin line. Lead ore has been mined at other places in Jo Daviess County, such as near Elizabeth, Apple River, and Warren. These occurrences increase the known mineralized district to include most of the county. Small amounts of lead ore are also reported to have been mined outside of this area near Freeport in Stephenson County and near Mt. Carroll in Carroll County.




Zinc-lead district of northwestern Illinois.

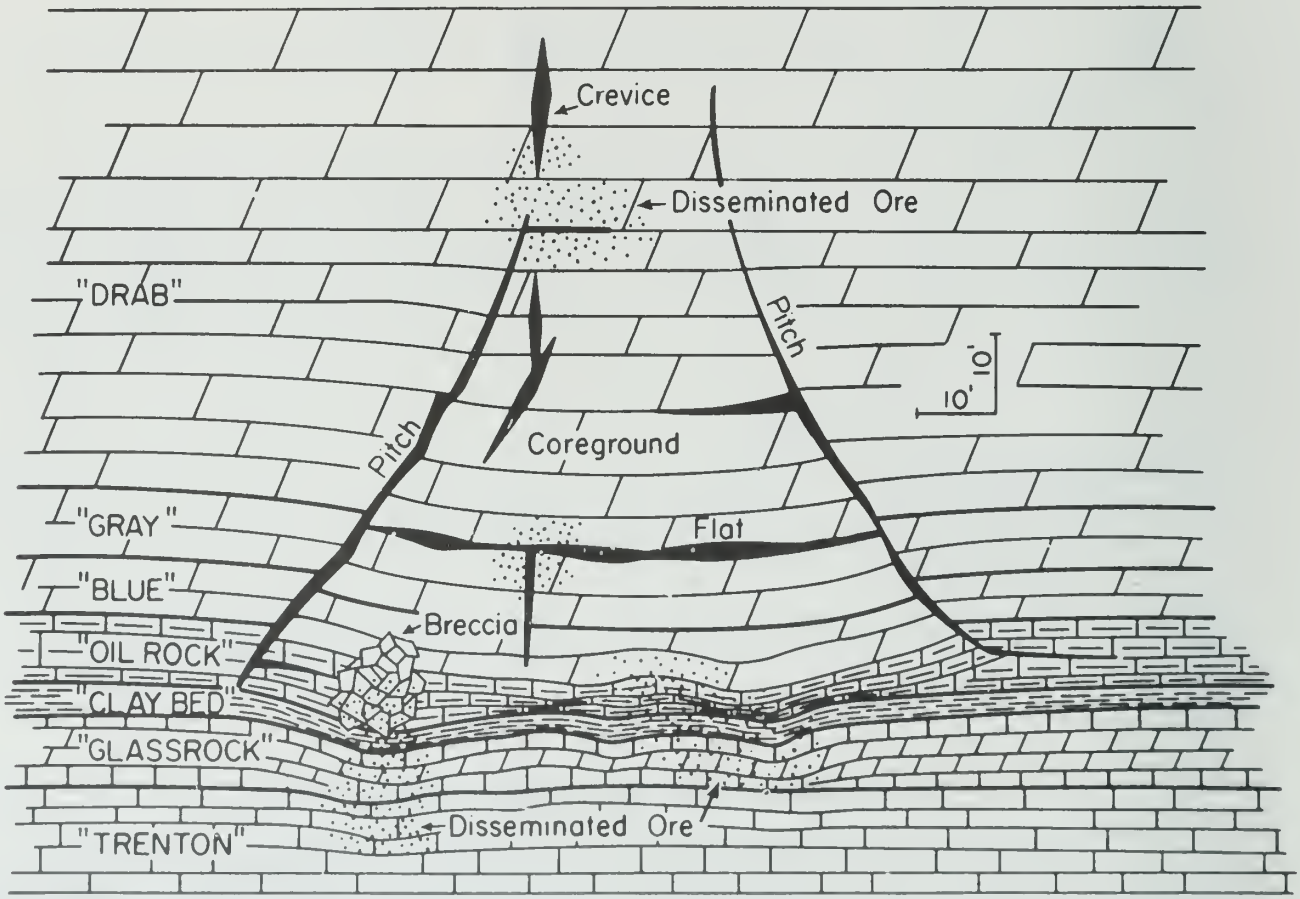
## Stratigraphic Position of Ore Deposits

The zinc-lead ore deposits occur in the middle Ordovician carbonate formations of the Galena and Platteville Groups (Champlainian Series) of the Ordovician System. The major deposits of zinc ore (sphalerite) are found in the lower part of the Galena Group, which includes the "Drab," "Gray," and "Blue" zones of the Dunleith Formation; the "Oilrock," or Guttenberg Formation; the "Claybed," or Spechts Ferry Formation; and in the "Glassrock," or Quimbys Mill Formation, which is in the top of the Platteville Group. These deposits are mainly of the "flat-and-pitch" type.

The major deposits of lead ore (galena) containing little associated sphalerite are found principally in the upper part of the Galena Group, which includes the top half of the Dunleith ("Drab") and the overlying Wise Lake Formation ("Buff"). These deposits are of the "crevice" type. Locally the lead ore may grade into mixed lead-zinc ore, especially in the lower part of the Wise Lake Formation.

## Flat-and-Pitch Deposits

The flat-and-pitch deposits in the lower ore-bearing zone consist of "flats," which are nearly horizontal, sheet-like bodies of ore between or parallel to the bedding planes of the strata, and "pitches," which are similar bodies cutting across the bedding planes. The pitches usually slope more than 45 degrees and many steepen upward to grade into vertical crevices. Some tend to flatten downward. The mineralized rock between pitches bounding an ore body is called the "coreground."



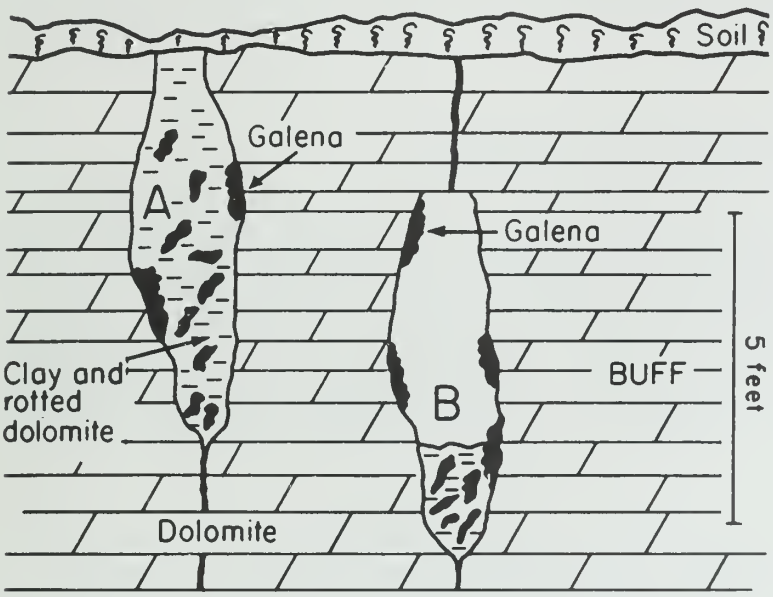

Flat-and-pitch ore bodies.

The flat-and-pitch deposits are associated with small synclinal structures, which trend northwest, northeast, or east. Between pitches bounding an ore body, the "Oilrock" and "Glassrock" are thinner than usual, apparently because of being dissolved away, and the overlying strata have sagged to form the synclinal structure. This sagging opened up the fractures which became mineralized. The mineralized sags are usually 50 to 200 feet wide, but may be as wide as 300 feet,

and extend longitudinally for thousands of feet in a straight line or in an arcuate manner. Usually the minable thickness is about 40 feet, but sometimes it is thicker. There are many variations in the shape and character of these deposits. The ore generally occurs as filled fissure deposits, but in the "Oil-rock" and "Glassrock" there are also disseminated-type deposits. Rarely the ore will assay as high as 20 percent zinc, but 10 percent zinc is considered rich ore and 3 to 4 percent ore is considered minable. In some deposits, minable ground is confined entirely to the pitches, but usually parts of the coreground are also minable. Minerals, other than galena, associated with the zinc ore (sphalerite) include pyrite, marcasite, and calcite. Above the water table, where oxidation has occurred, there are secondary minerals including cerussite (lead carbonate), anglesite (lead sulfate), smithsonite (zinc carbonate), and limonite (iron oxide).

## Crevice Deposits

The crevice deposits of the upper mineralized zone occur as fissure fillings along joints that are oriented mainly in an east-west direction. The crevices are actually vertical fissures, or cavities, that were opened up along the joints by solution of the dolomite. Along a typical crevice the minable ore occurs as pods or lenses a few feet to a few hundred feet long scattered along the strike of the joints. The ore bodies are generally only a few inches to a few feet wide, but where there are two or more closely spaced crevices, they extend over widths of 30 feet or more. The ore is usually pure galena, but locally it may grade to mixtures of galena and sphalerite.




Crevice ore bodies. Crevice A reaches the ground surface and is filled with clay; B is only partly clay-filled.

The shallow crevice deposits were the nation's principal source of lead ore between 1820 and 1865. These deposits were easily discovered in partial exposures along stream valleys and by the presence of residual accumulations of ore where erosion had intersected mineralized joints. In some cases the topographic expression of crevices as shallow depressions led to the discovery of ore bodies. When these easily exploited deposits were depleted, lead ore production declined sharply. At present, little ore is mined from shallow deposits each year. Zinc ore obtained almost exclusively from the larger, deeper flat-and-pitch deposits is now the chief mineral commodity of the area.

## Origin of Ore Deposits

The origin of the ore bodies is still in question. An early theory that was widely accepted is the "cold water theory." By this theory the lead and zinc minerals were assumed to have been present in trace quantities disseminated throughout the Galena Dolomite or higher rock units. The lead and zinc were originally supposed to have been deposited with the carbonate rocks when they were precipitated from the ancient Ordovician sea more than 400 million years ago. Percolating ground water then dissolved the lead and zinc minerals from these rocks and carried them downward to be reprecipitated in openings in the strata where the ore is now found.

The theory now generally favored by geologists is the "magmatic theory." According to this theory the ore was emplaced by hydrothermal solutions rising from a deep magmatic (igneous) source. The warm mineralized solutions ascended until they encountered the cavernous, jointed Champlainian (middle Ordovician) rocks that had the proper temperature-pressure conditions to allow the precipitation of the lead and zinc sulfides. The neutralizing effect of carbonate-rich ground water on the acid sulfide-bearing solutions could also have been partly responsible. These ideas may explain why the ore bodies are restricted to such a narrow vertical interval of Ordovician strata. However, the absence of deep downward extensions of ore and major faults that could have provided access to the rising solutions has not been resolved.

The open fissures in which the crevice ores were deposited and the synclinal structures associated with the flat-and-pitch ore bodies are solutional in origin and were formed before ore emplacement. Whether solution was by meteoric ground water or by hydrothermal solutions has not been definitely determined. If the latter is true, the openings may have formed contemporaneously with ore deposition.

## Prospecting for Ore Deposits

The long, fairly narrow ore bodies in the Upper Mississippi Valley zinc-lead district, especially the deeper ore bodies, are difficult to find. To extend the life of the mining district new reserves of ore must be found. Geophysical and geochemical methods have been used in the exploration for ore deposits to some extent, but with limited success. Drilling is the most commonly used means of prospecting for lead and zinc ores and is at present the most effective method of searching for the deep ore bodies. Drilling is used to explore the trends of known ore deposits and to search for new ore bodies in previously untested areas.

Recent prospecting for lead and zinc ores in northwestern Illinois has consisted largely of drilling in areas of old shallow lead diggings, along the trends of known deeper ore bodies, and in the vicinities of the occasional water wells that happen to penetrate ore. "Wildcat" holes drilled in unproven ground outside areas of known ore deposits have been relatively few. Before deciding where to drill such exploratory holes, many interrelated geologic factors must be evaluated by the geologist.

Churn drilling. There are two principal methods of drilling deep holes—churn drilling and rotary drilling with a diamond bit. Churn drilling, also known as cable-tool drilling, is much less expensive than diamond drilling and has been used widely in the zinc-lead district for deep prospecting. By this method six-inch vertical holes are drilled by a heavy steel rock bit suspended from a steel cable that is attached to the controlling machinery at the surface. The heavy bit is alternately lifted and dropped, the rock being penetrated by the repeated blows of the bit. The broken rock is periodically bailed from the hole, and samples of the rock chips are saved for examination or assaying.

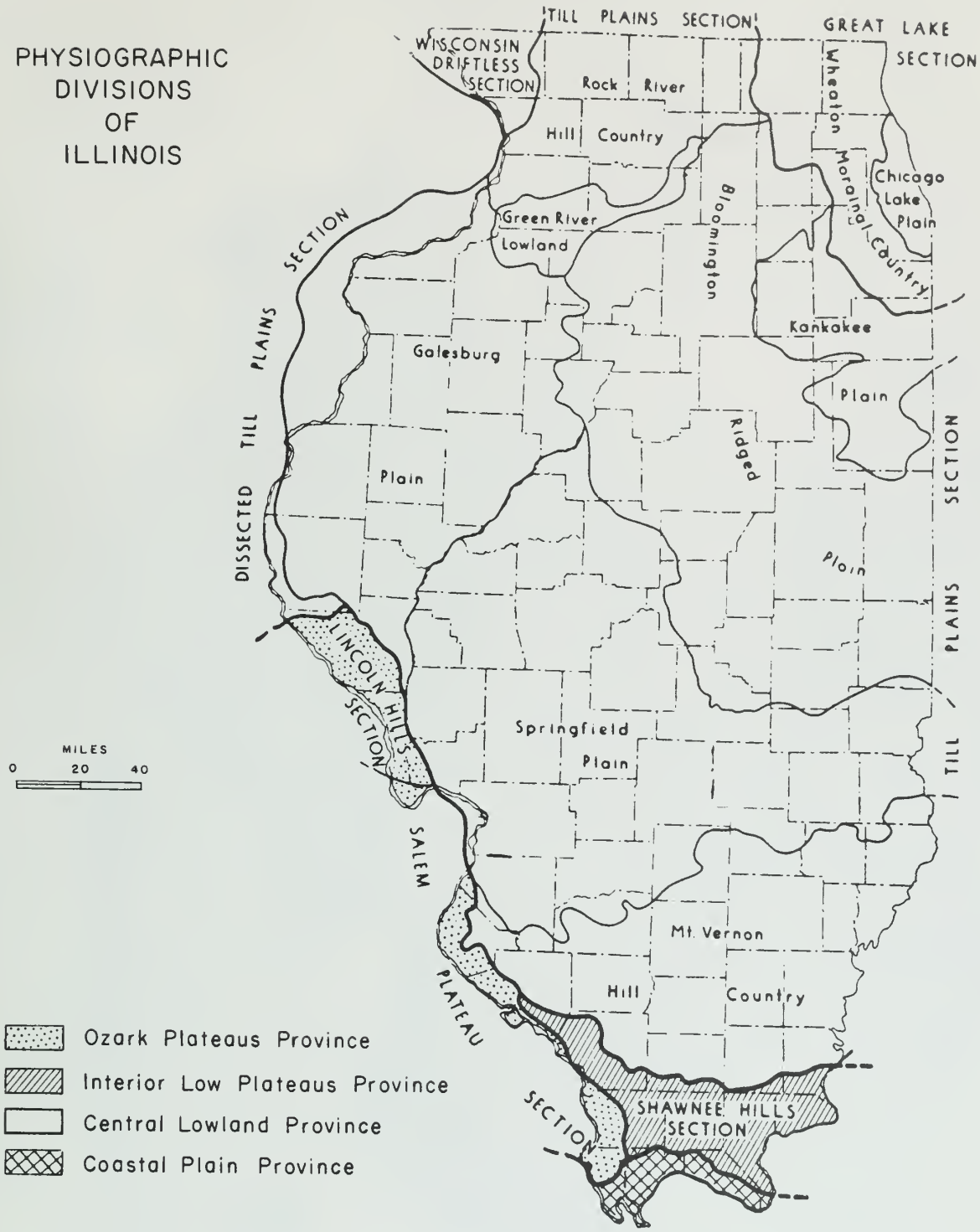
Diamond drilling. Diamond drilling provides better rock samples than those obtained by churn drilling, if core recovery is good. The cores obtained are continuous samples, or a column, of the rock interval that is penetrated by the bit. However, in soft or fractured rock, often in critical zones of mineralization where samples are most desired, poor core recovery may result in no sample for some intervals. A definite advantage of diamond drilling is the ability to drill inclined holes. Drilling is accomplished by means of a small-diameter diamond bit attached to a column of pipe called the drill stem. The bit cuts through the rock when the drill stem is rotated by power machinery at the surface. Water or a water-oil mixture is pumped down the inside of the drill stem under pressure to cool and lubricate the diamond bit and to flush out crushed rock from the bottom of the hole and carry it up the drill hole to the surface. The rock core enters the hollow drill stem, where it is surrounded by the coolant as the bit cuts downward, and it remains there until it is retrieved when the drill stem is pulled out of the hole. Depending upon the depth to be drilled, the diameter of the drill stem and bit are usually decreased periodically as the hole deepens.

TIME TABLE OF PLEISTOCENE GLACIATION

| STAGE | SUBSTAGE | NATURE OF DEPOSITS | SPECIAL FEATURES |
|---|---|---|---|
| HOLOCENE | Years Before Present | Soil, youthful profile of weathering, lake and river deposits, dunes, peat | |
| | 7,000 | | |
| WISCONSINAN (4th glacial) | Valderan | Outwash, lake deposits | Outwash along Mississippi Valley |
| | 11,000 | | |
| | Twocreekan | Peat and alluvium | Ice withdrawal, erosion |
| | 12,500 | | |
| | Woodfordian | Drift, loess, dunes, lake deposits | Glaciation; building of many moraines as far south as Shelbyville; extensive valley trains, outwash plains, and lakes |
| | 22,000 | | |
| | Farmdalian | Soil, silt, and peat | Ice withdrawal, weathering, and erosion |
| | 28,000 | | |
| | Altonian | Drift, loess | Glaciation in northern Illinois, valley trains along major rivers |
| | 75,000 | | |
| SANGAMONIAN (3rd interglacial) | | Soil, mature profile of weathering | |
| | 175,000 | | |
| ILLINOIAN (3rd glacial) | Jubileean | Drift, loess | Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois |
| | Monican | Drift, loess | |
| | Liman | Drift, loess | |
| | 300,000 | | |
| YARMOUTHIAN (2nd interglacial) | | Soil, mature profile of weathering | |
| | 600,000 | | |
| KANSAN (2nd glacial) | | Drift, loess | Glaciers from northeast and northwest covered much of state |
| | 700,000 | | |
| AFTONIAN (1st interglacial) | | Soil, mature profile of weathering | |
| | 900,000 | | |
| NEBRASKAN (1st glacial) | | Drift | Glaciers from northwest invaded western Illinois |
| | 1,200,000 or more | | |

(Illinois State Geological Survey, 1973)

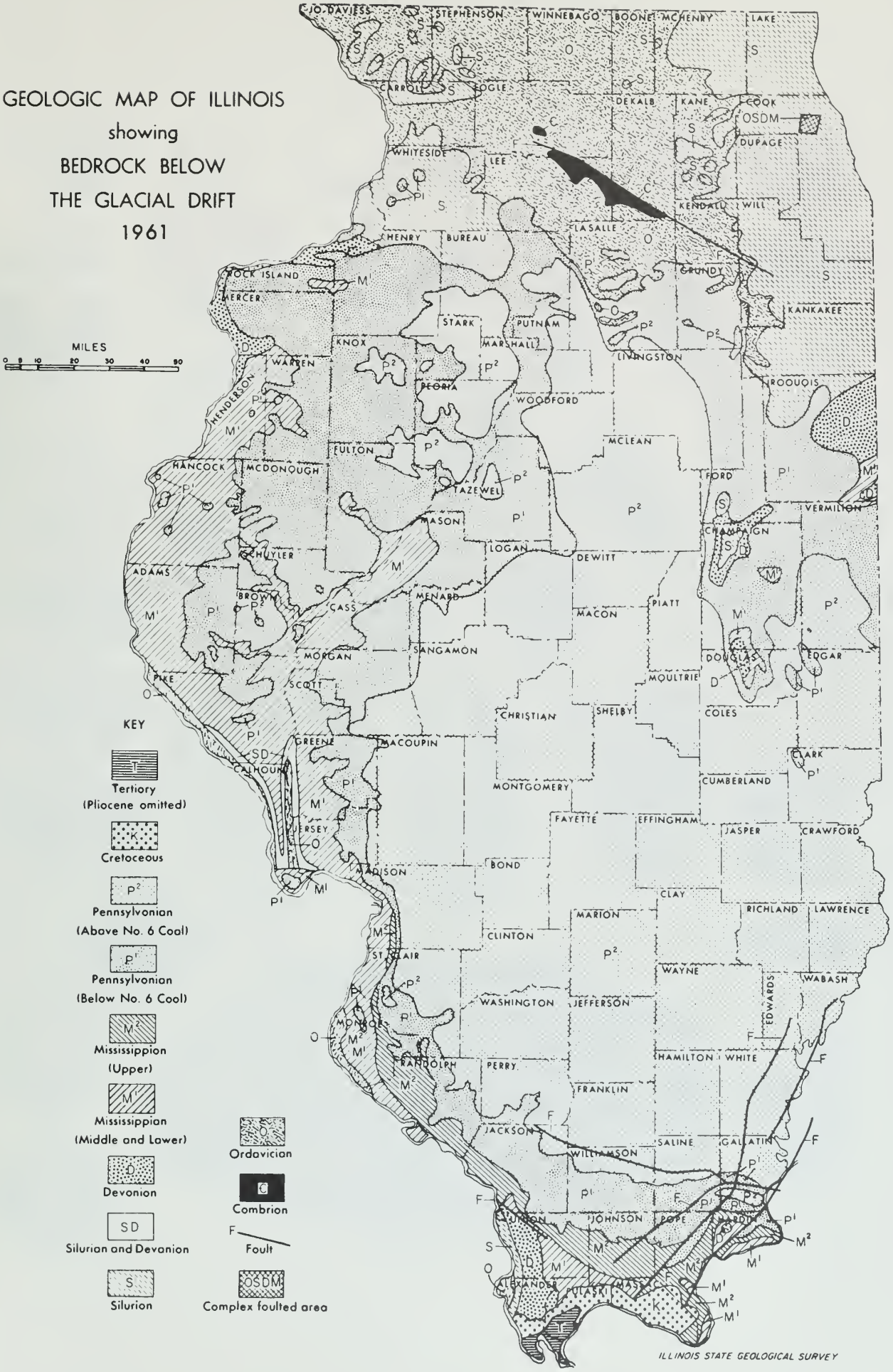
# PHYSIOGRAPHIC DIVISIONS OF ILLINOIS



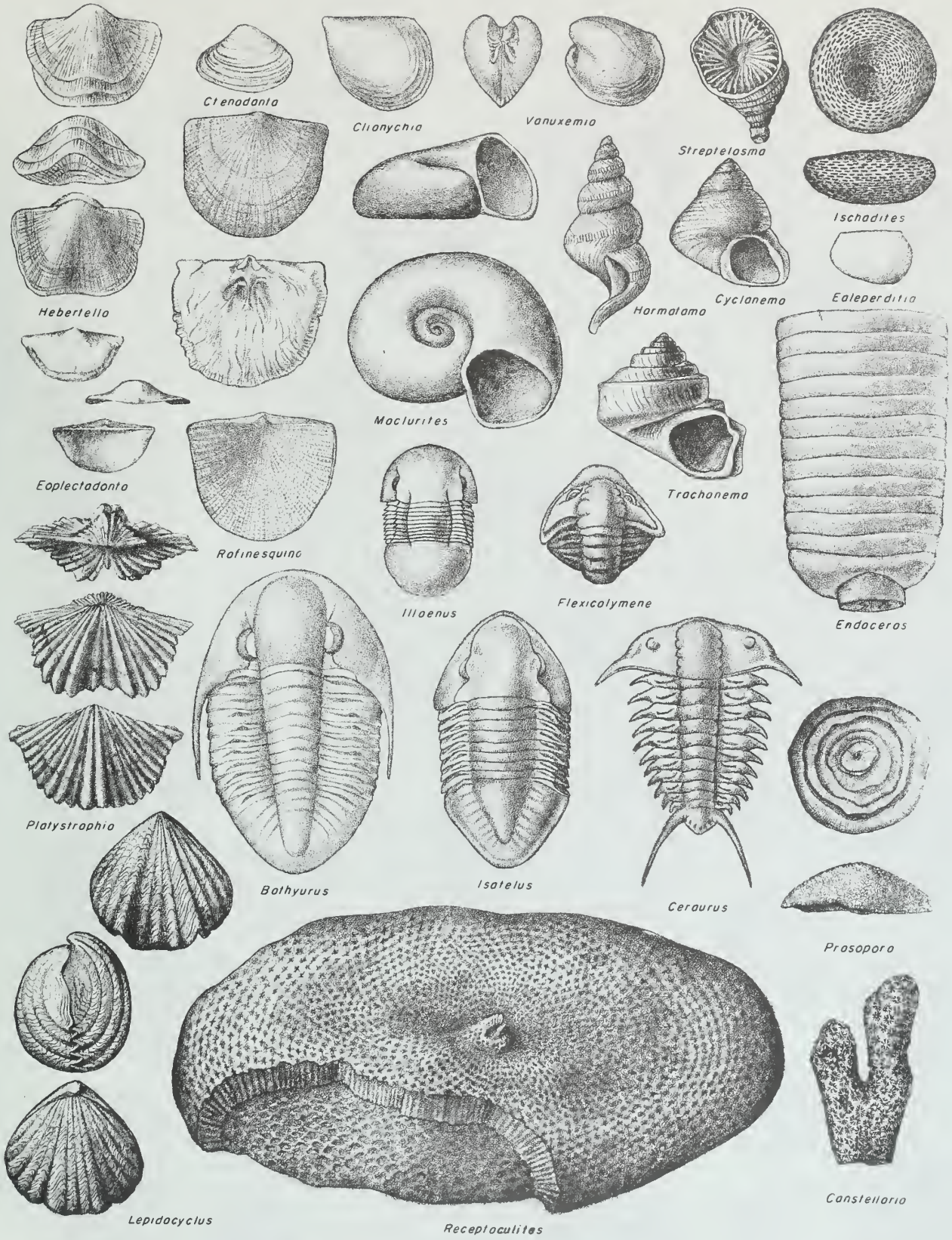

Reprinted 1970

ILLINOIS STATE GEOLOGICAL SURVEY

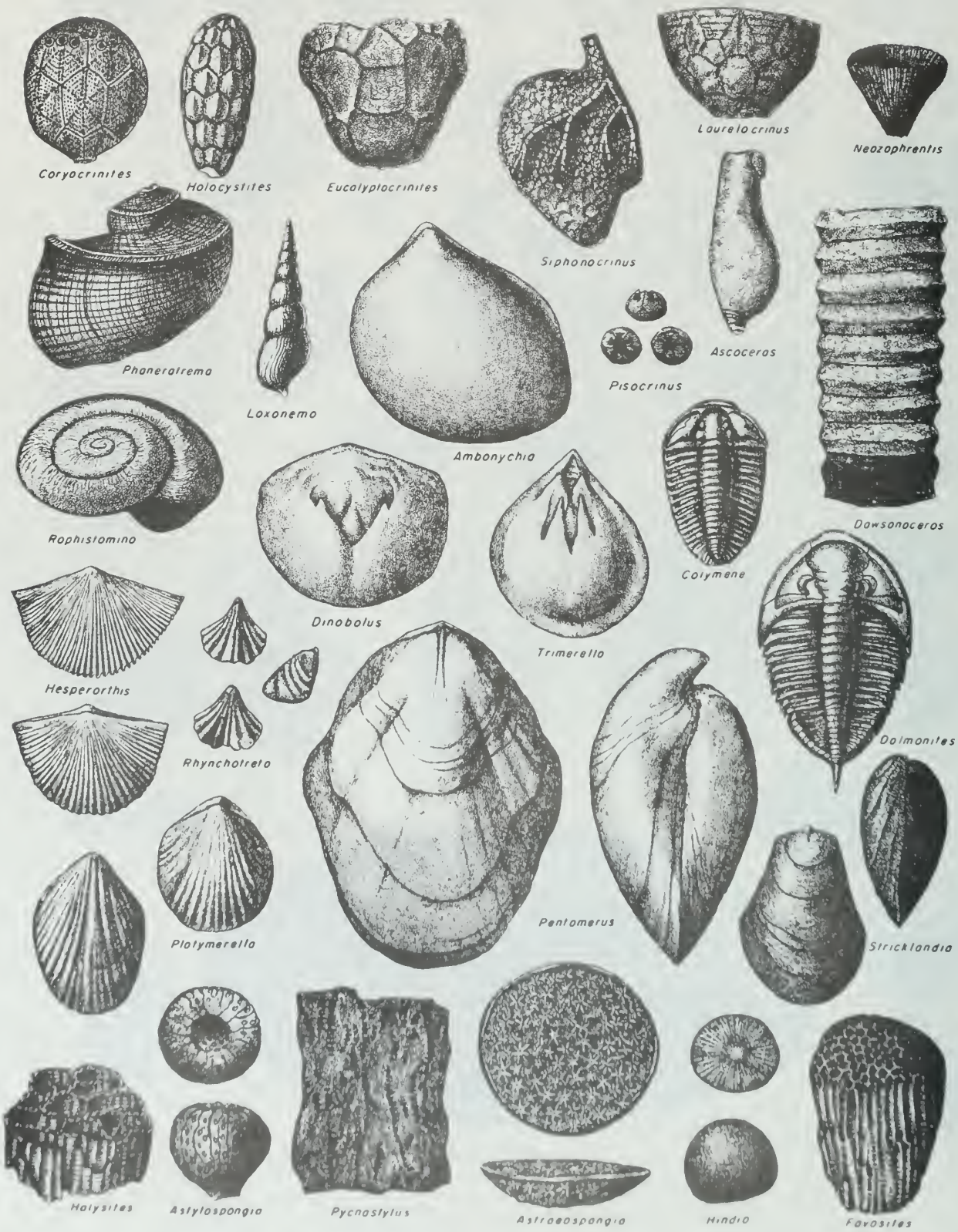
# GEOLOGIC MAP OF ILLINOIS
showing
BEDROCK BELOW
THE GLACIAL DRIFT
1961

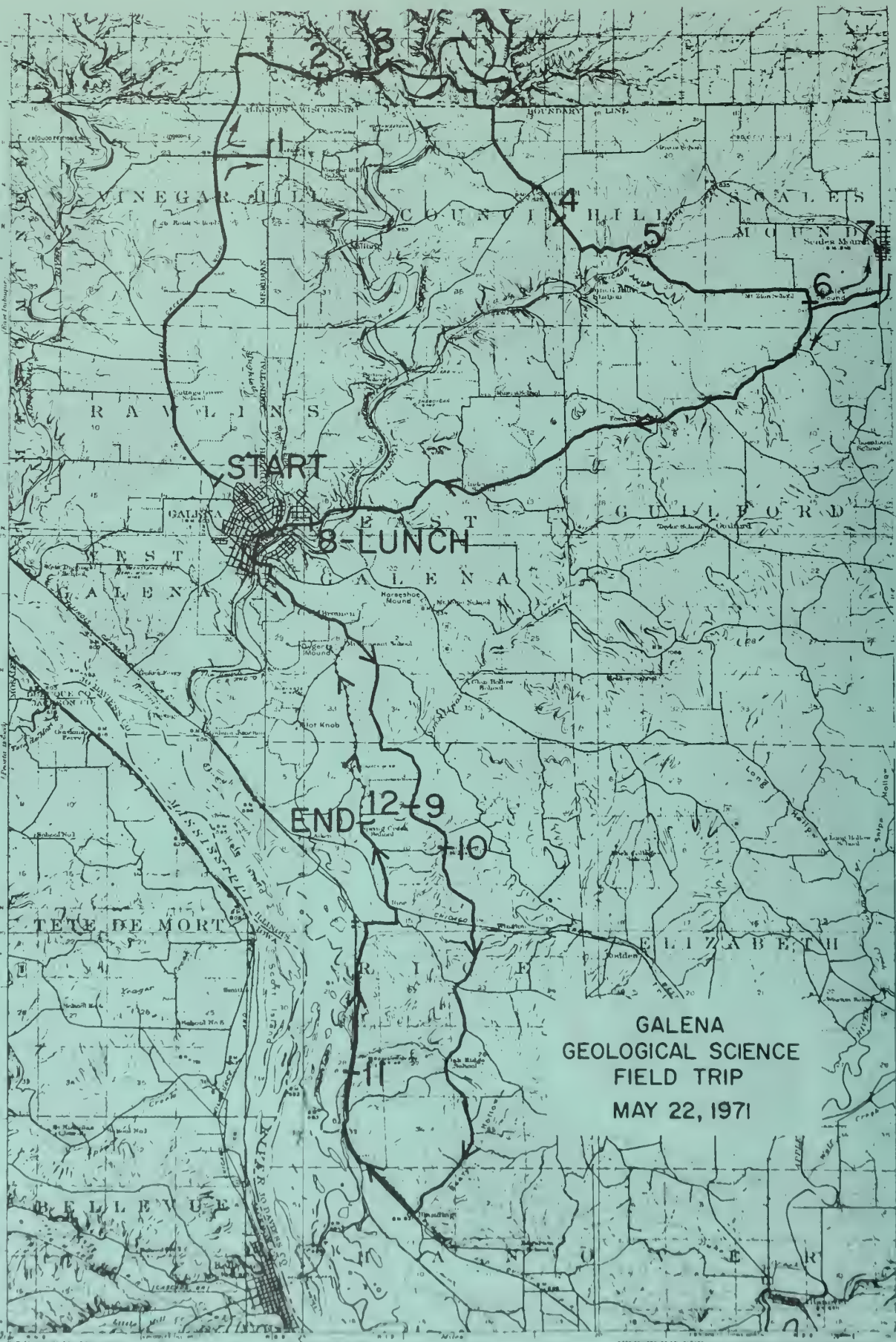


# ORDOVICIAN FOSSILS



REPRESENTATIVE SILURIAN FOSSILS FROM NORTHWESTERN ILLINOIS




GALENA
GEOLOGICAL SCIENCE
FIELD TRIP
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START
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VINEGAR HILL
COUNTY
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SCALES
MOUND
RAWLINS
GUILFORD
WEST
GALENA
EAST
GALENA
TETE DE MORT
ELIZABETH
BELLEVUE
MISSISSIPPI
RIVER
Horseshoe Mound
Hot Knob
Sandy Mound
Long Hollow
Long Hollow School
Dodge School
Oakland
Dyer School
Mt Zion School
Ford School
Lockwood School
Lockwood
Pleasant Valley School
Pleasant Valley
Chicago
Boulder
Hoagar
Bellevue
Bellevue Junction
Hillsdale
Hillsdale School
Bellevue Junction School
Bellevue Junction Station
Bellevue Junction Bridge
Bellevue Junction Cemetery
Bellevue Junction Church
Bellevue Junction Parsonage
Bellevue Junction Post Office
Bellevue Junction Public Schools
Bellevue Junction Public Schools Gymnasium
Bellevue Junction Public Schools Auditorium
Bellevue Junction Public Schools Athletic Field
Bellevue Junction Public Schools Tennis Courts
Bellevue Junction Public Schools Baseball Diamond
Bellevue Junction Public Schools Football Field
Bellevue Junction Public Schools Track
Bellevue Junction Public Schools Swimming Pool
Bellevue Junction Public Schools Playground
Bellevue Junction Public Schools Parking Lot
Bellevue Junction Public Schools Bus Garage
Bellevue Junction Public Schools Maintenance Shop
Bellevue Junction Public Schools Administration Building
Bellevue Junction Public Schools Cafeteria
Bellevue Junction Public Schools Library
Bellevue Junction Public Schools Science Building
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Bellevue Junction Public Schools Agriculture Building
Bellevue Junction Public Schools Home Economics Building
Bellevue Junction Public Schools Industrial Arts Building
Bellevue Junction Public Schools Band Building
Bellevue Junction Public Schools Choir Building
Bellevue Junction Public Schools Dormitory
Bellevue Junction Public Schools Faculty Housing
Bellevue Junction Public Schools Student Housing
Bellevue Junction Public Schools Dining Hall
Bellevue Junction Public Schools Kitchen
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